Alternate Technologies

The microwave system is compared in this note to optical and leaky feeder technologies. The issue of analogue versus digital transmission is also discussed.

Microwave vs Optical

Microwave is not unduly sensitive to layers of brake dust or grease. The results from extensive long term trials at London Underground stations showed that the reduction in signal strength due to the accumulation of dust and other substances was virtually unmeasurable.

Against this optical systems, whether IR or laser based, are particularly vulnerable. Similar trials showed that a covering of dust on the equipment affected the sensitivity to such an extent that the video availability was reduced by 25%. The results can be provided on request. From this, the obvious conclusion is that IR systems will require frequent routine maintenance to ensure satisfactory operation, whereas microwave will not.

In addition, microwave transmissions can tolerate heavy rainfall, fog and mist with relatively little attenuation. Over the ranges required in a typical system, the attenuation, even under very heavy downpours of 100 mm/hour, will be less than 0.6 dB. Conversely optical systems are very susceptible. This is especially true when appreciable de-focusing of the beam is used to widen the beam to accommodate track curvature with a reasonable tolerance.

Alternatively, if the de-focusing is reduced such that it just covers the movement of the train, the alignment requirements then become particularly critical and periodic checks will be necessary to ensure that the geometry is correct, with neither the transmitter nor the receiver having been inadvertently moved out of position.

This approach also imposes severe problems if different types of rolling stock use the same track and if, as is likely, the trainborne receivers have to be placed at different positions. Either the beam has to be sufficiently wide to cover all possible train installations, or constraints have to be imposed on the installations, which may involve additional costs.

In contrast, because microwave systems have an inherently long range, they can employ far wider beams, which in turn minimises the constraints on the receiver installation and avoids the need for precise transmitter or receiver alignment.

A further limitation of optical systems is that a true line of sight is required. This means that on curved tracks typical of many networks, a large number of transmitters have to be installed to guarantee uninterrupted coverage. Against this microwave systems do not require true lines of sight because the beams reflect off the wall of the tunnels. This means that in tight track conditions appreciably fewer transmitters can be used. Typically there can be a 50% reduction in number.

The problem for optical systems is compounded if there are multiple tracks running close to one another. Here it is essential that the beams from one track cannot under any circumstances be received by trains on any other track. In situations where the tracks also curve, the layout of the optical Transmitters becomes particularly complex and in some cases, perhaps impossible. Against this, microwave systems can simply use different frequencies to ensure isolation between the tracks.

These factors, taken together complicate the installation requirements of optical transmitters. They impose constraints on the location of the sites, they increase the number of transmitters required to cover curved tracks and involve frequent maintenance to ensure optimal performance. None of these problems exist with microwave solutions.

Microwave vs Leaky Feeder

Leaky feeder cables have been used in the first generation of track to train transmission systems. Their major disadvantage is associated with the particularly demanding installation requirements and its impact on track maintenance work, which in turn can lead to a high cost of ownership.

Leaky feeders comprise coaxial cable or waveguide with slots or holes cut at regular intervals. The feeder has to be laid continuously along the track where the transmission is required. The location and orientation of the feeder is always critical.

The problems imposed by this are that the cables are vulnerable to damage, simply because of their position on the track. Also, maintenance work can necessitate the removal and precise replacement of complete sections of the feeder.

The difficulties are exacerbated as the cables are relatively fragile and not designed for movement after fitting. They are compounded further by embrittlement, which occurs over time. Against this, waveguide is not flexible and necessitates great care when long lengths are moved. It also requires continuous pressurisation with dry air to avoid condensation during temperature changes, which would otherwise cause corrosion.

Finally, because there are two modes of propagation along a leaky feeder and because they travel with different phase velocities, there is a considerable amount of nulling along the length of the feeder. This can result in significant power variations, which in turn can result in poor video quality and the increased likelihood of cross-talk from adjacent tracks.

These problems can be overcome by the use of frequency diversity and by using different frequencies on different tracks, but because there is limited spectrum in the bands in which leaky feeders can operate, there is a limited capability to implement these options. To the best of our knowledge no leaky feeder solution has the capability, which is why many problems exist in practical implementations.

Finally because leaky feeders are operating at the limits of their capacity, there is very little growth potential to transmit other revenue earning services or to implement two-way transmission. Against this, there is 600 MHz of capacity available with the microwave solution, which means there is tremendous growth capacity for future expansion.

Analogue vs Digital

1 General

Two microwave options are possible. One is analogue, the other digital. The majority of the units and modules are common to both options, the only difference being in modulator and demodulator modules that are fitted in the two versions

The analogue system uses wideband FM to provide a high level of broadcast quality video with no latency. Its disadvantage is that it requires a near line of sight between the transmitter and receiver. This means that it will be necessary to install additional transmitters if there is significant curvature over the coverage area that fully obscures the train.

Against this, the digital solution can operate under most non line of sight conditions. The preferred standard is DVB-T which is identical to that used by all the world's terrestrial broadcasters. It uses COFDM modulation by spreading the data over 2,000 carriers, which effectively means that each carrier is operating at very slow data rates. Because of this it can operate in reflection rich environments and can perform to full performance just on reflected signals. Two receive antennas improves the performance even more by providing space diversity in exactly the same way as in the analogue system.

There are other digital COFDM equipments available. The most common is Wi-Fi, as used in laptops and other short range devices. The disadvantage of this technology is that it uses only 64 carriers rather than 2,000 and so is less effective. It operates in the licence exempt or public bands, which means that it is very susceptible to interference. It also has a limited data capacity, which can seriously compromise the video performance.

A later version of this technology is Wi-Max, which has been designed as a long range version of Wi-Fi. Despite this, it is still markedly worse than DVB-T in that it has only 256 carriers, is only effectively available in the licence exempt bands and has much more limited data rates than DVB-T. For all these reasons DVB-T is the preferred digital solution.

2 Compression

Analogue transmission provides high quality video in a moderate bandwidth. Appreciably more spectrum is required to achieve the same quality level in a digital system if all the data is used. This is overcome in practical systems by compression, the applicable common standards of which are MPEG2 and MPEG4.

MPEG2 is the standard optimised for use in high quality broadcast systems, whereas lower data rate equipments such as those employed in IP or broadband networks use MPEG4. Given a choice between the two for this application, it is obviously essential that the images should be as easy to read as possible, especially since split second actions have to be taken. Thus the transmission should provide the highest quality possible, which means MPEG2 rather than MPEG4.

Both systems use historical data from previous frames and therefore only need updates to those parts of the picture that differ from one frame to another. Although this is useful in reducing the data rate, it introduces the vulnerability of frozen pictures and long-term blockiness, depending on how the errors are handled. It can take several seconds to re-enable the synchronisation and clear any artifacts from the screen or unfreeze the frame. An analogue system in contrast will show interference on the image just as long as the poor transmission exists.

Another factor that limits the use of digital compression in real time applications is the encoding and decoding time. Even a delay or latency of 50 mS, that is short by most standards, is still an appreciable fraction of the human reaction time. When real time decisions have to be made, even delays this short may be of significance. Against this, the latency of the analogue system is effectively zero.

3 Conclusions

The advantage of COFDM digital transmissions is that they can operate in non line of sight conditions because they have the ability to operate on reflected signals, which means that fewer transmitters are required. However there will always be some latency due to the compression process. Also, they can give either no images, or unusable / misleading images under poor transmission conditions.

On balance therefore, our recommendation is that if the ranges are long and there are difficult line of sight conditions, the digital option is probably the best solution. However if the ranges are short and if generally there is a line of sight, the preferred option will often be analogue.

The fact that we can supply both options enables us to be totally impartial in the choice of system. This enables us to offer the best solution for any set of conditions, rather than try to promote one particular solution only, even if it is not the optimum.