SCTE Network Technician's Course

Working for the Benefit of the Broadband Industry

Reference Manual

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Welcome to the SCTE Manual

This handbook is designed as a stand-alone reference manual for technicians working in the broadband telecommunications industry. It may be used either on its own or as an integral part of a classroom course including practical work to enable the student to progress to examination and certification.

We hope you and your career benefit greatly from this handbook and associated training course. Please consider joining the SCTE and taking advantage ofthe benefits that come from being part of the industry's foremost technical institution.

About the SCTE

Founded in 1945, the SCTE is a non-profit making organisation, managed by an Executive Committee of elected volunteers, whose aim is to raise the standard of broadband engineering in the telecommunications industry. The Society particularly concerns itself with the training and career advancement of technical professionals in this field.

First introduced in 1994, the SCTE training courses have achieved wide acceptance as the standard for young technicians wishing to enter the field of cable telecommunications and for those wishing to advance their knowledge and career prospects. They are used in-house by a number of operating companies and SCTE engineers can be found working in a variety of international organisations.

As a Learned Society, SCTE is able to provide accreditation and certification for its members, giving them professional standing within the industry. Full Members and Fellows are allowed to use the designations MSCTE and FSCTE after their names whilst Technician Members may use TMSCTE. There are also categories for Student and Associate Members which carry the designations SMSCTE and AMSCTE respectively.

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Published by the SCTE, Communications House, 41a Market Street, Watford, WD18 0PN UK

First published in UK in 2009. ISBN No: 978-0-9563335-5-1

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Section One

1.1 Introduction

Network technicians are defined as the senior technicians in a cable operator's staff, who will normally be involved in two main activities; a) commissioning new networks and b) restoring the service on existing networks. They would not normally be involved in work at the headend.

Modern networks are constructed with a mixture of copper and fibre optic links; some are all fibre, which means that the network technician needs a range of skills. Although most television transmissions are now digital multiplexes many networks still carry analogue channels, both are addressed within this course.

1.2 Commissioning Networks (see Section 2 for more details)

This activity follows on from the network design and construction stages that are normally carried out by specialist teams. Network design is normally an "in-house" activity whereas construction, especially civils i.e. digging roads and pulling in cables, is contracted out. Although new networks are now very seldom constructed, the build programme is now largely completed in most of Europe, cable operators are almost continuously engaged in upgrading their networks. This work has recently taken on a greater urgency as cable operators are implementing/upgrading return paths from subscribers. With this need to provide a reliable return path, the advent of digital TV and other data services has meant that cable operators always have a programme of network upgrades. It is in this capacity that network technicians will need to have the skills necessary to commission newly upgraded networks.

Commissioning work can be broken down into two activities:

1.2.1 Setting up the Equipment/Network

This work may involve checking over and testing work carried out by sub-contractors. Fitting connectors to main-line coaxial cables requires careful checking to ensure that low loss and good return loss (RLR) connections are made. There is a need to be conversant with insertion loss and return loss measurements.

In setting up a network it is necessary to ensure that amplifiers' input and output levels are correctly adjusted, using properly calibrated accurate level measurement equipment such as spectrum analysers. The frequency response of the network must be checked, using sweep equipment, and the correct values of equalisers inserted in the amplifiers. This process nowadays involves sweeping both the forward and the reverse paths.

Fibre optic cable installation is often carried out by specialist contractors, who invest the large sums necessary to purchase the range of fusion fibre splicing and testing equipment. Nevertheless it is important that network technicians should be familiar with the techniques used in splicing and testing fibre optic. Optical Time Domain Reflectometers (OTDRs) are important tools for these measurements; they will allow splice losses and reflections to be measured.

Fibre optic transmission equipment such as laser transmitters, amplifiers and receivers need to be correctly set-up. Although the procedures vary for equipment from different vendors, the process must at least include making optical power level measurements.

1.2.2 Testing the Network

Testing the network can be part of a regular preventive maintenance programme or in response to a reported network fault. There is no difference between the measurements carried out under each of these headings except for the urgency in which they are normally required (live network with connected subscribers must be repaired quickly).

1.3 Restoring the Service

Network technicians occasionally have to troubleshoot faults right up to the customer's home connection e.g. when a fault has been diagnosed by the service technicians as emanating from the network. Network technicians must be able to diagnose and remedy faults in the same way as service technicians but must also have the skills necessary to troubleshoot deeper into the network, in some cases back to the headend.

The sub-sections that follow give further details of some of the tasks that network or system technicians will undertake in the course of their duties. More details on the equipment, methods of measurement and test equipment will be found in the second part of the Network Technician course entitled "Network Architecture and Design".

1.3.1 Power Supply Measurements

1.3.1.1 CATV Network

The CATV coaxial network from the fibre optic receiver node down towards the distribution cabinets is powered over the coaxial cable. The supply voltage can be anywhere between 40 and 90 volts 50/60Hz (depending on the local regulations) which is derived from the mains electricity supply at the hub cabinet. The power supply is either the ferro-resonant type, or a switch mode supply which often incorporates a standby facility for battery backup. The output waveform from a ferro-resonant supply is not sinusoidal, but is referred to as quasi-square wave (square wave with the edges rounded to remove the high frequency components). The power is injected into the coaxial by the "power supply inserter" and bypassed around network passives.

The quasi-square waveform from a ferro resonant supply means that the measurement of the output voltage produced by a ferro-resonant supply is dependent on the type of voltmeter used. The most accurate result is obtained by using an oscilloscope that will actually measure the peak-to-peak voltage of the supply and dependent on its waveform suitable correction factors may be applied to establish its true RMS value. Oscilloscopes however are not very convenient to use in the field and digital multimeters are probably the most common test equipment used for power supply measurements.

A true RMS voltmeter will give the most accurate reading and should be used when possible. A standard digital voltmeter will convert AC to DC (average voltage); the instrument calibration is then multiplied by 1.11 to produce an RMS reading for a sinusoidal signal. This procedure is reasonably accurate when measuring a sinusoidal supply, such as the mains, but is not accurate for measuring quasi-square waveforms. The reading will normally be higher than the true RMS value of a quasi-square wave where the RMS and average voltages are the same. Corrections factors must therefore be applied to standard digital voltmeter

readings to compensate for this effect. Also, the characteristics of ferro-resonant supplies produce an output waveform that becomes more sinusoidal as the loading is increased. Typically, a standard digital multimeter will produce an error of some 8% when the supply is lightly loaded reducing to about 3% when the supply is fully loaded.

Power supplies should form part of any preventive maintenance schedule as a critical component that can interrupt the service to very many customers. Some cable operators employ stand-by battery supplies for the more critical coaxial cable distribution equipment. However, as the fibre optic cable distribution penetrates closer to the customer, this practice may disappear. As the coaxial cable segments support far fewer customers, this makes the use of stand-by supplies for CATV unusual. The fibre optic network often uses stand-by supply power supplies for lasers and optical receivers.

1.3.1.2 Telephony Network

The telephony network, at the hubs, will normally accommodate a number of primary rate multiplexers that are mains powered and have stand-by supplies. This is a pre-requisite of a telephony system in order that the service is protected from local electricity supply failures.

Downstream of the hubs, the telephony network is passive, i.e. copper pairs are taken to further distribution points in street cabinets or underground chambers. There is no requirement for any power supply to energise further network equipment. A 50 volts DC supply is still needed on the cable to every customer, in order to energise the customer's telephone equipment.

1.3.2 Coaxial Cable Measurements (see Section 3 for more details)

Technicians will often need to carry out measurements on coaxial and optical cables to establish when and how characteristics have departed from the norm. The three most common are "cable attenuation, return loss and impedance.

1.3.2.1 Cable Attenuation

Measurement of coaxial cable attenuation is carried out by means of a Signal Level Meter (SLM), ranging from hand held units to sophisticated spectrum analysers. The ratio of the signal level at the output of a section of cable to that at the input to that section is expressed in decibel per unit length.

Cable attenuation varies with frequency, it is therefore necessary to carry out the measurement at a number of frequencies. Spectrum analysers can assist in simplifying this function.

1.3.2.2 Impedance or Return Loss Ratio

The standard characteristic impedance of CATV cable is 75 ohms. Variations from this standard impedance are sometimes made when problems are present. Mismatch can cause ghosting on analogue signals and a high BER/low MER on digital signals; it can be detected by the use of time domain reflectometry. Some defects or faults occurring at regular intervals, known as structural return loss faults, require different measurement techniques which are used during the manufacture of the cable. These are not normally carried out on installed cable.

1.3.2.3 Time Domain Reflectometer (TDR) Measurements

The TDR equipment generates a short pulse of RF energy that is fed into the length of cable network under investigation. Whenever a mismatch occurs, due to either a cable fault or some network passive fault, some of the energy is reflected back towards the TDR. The time taken for the reflected energy to be detected at the TDR is used on a display that is calibrated in distance to the fault. The amplitude of the reflection gives an indication of the magnitude of the mismatch.

This test is intrusive; i.e. the service must be interrupted, and should only be used when absolutely necessary. TDR measurements are ideally suitable for establishing the location of faults in underground network.

1.3.2.4 Telephony Cable Measurements

The nominal telephony network impedance is 600 ohms although this is not tightly controlled. Cable attenuation is not often measured and it is more common to check the cable DC resistance. Location of faults in underground networks can also be accomplished by using TDR equipment with suitably adapted output connections i.e. 600 ohms balanced. Severe mismatches on telephone pairs can have a detrimental effect on DSL service whilst not causing problems with standard telephone service.

Specialised equipment is available for tracking down more obscure faults such as crosstalk between pairs of a multipair cable.

1.3.3 Replacement and Setting Up of Amplifiers

The advent of fibre optic transmission has meant that the very long chain of cascaded RF amplifiers are no longer used in modern CATV networks. The modern architectures where the fibre optic receiver hubs feed a coaxial cable network with a maximum of 400 - 500 homes means that a cascade of two or three RF amplifiers is probably the most that any customer is likely to experience. However, the fact that RF amplifiers are on the decline does not mean to say that their set up procedures should be neglected; otherwise the enhancement to picture quality due to fibre optic transmission will soon be dissipated.

Whenever an amplifier has to be replaced, the technician will be required to check the input and output levels against the design figures. Attenuators and equalisers will need to be selected accordingly. In theory replacement of an amplifier should only require that the plug-in devices (attenuators and equalisers) in the faulty amplifier should be placed into the replacement one if it is the same type. However attenuators and equalisers should always be adjusted to restore the original levels, this is especially so where variable or electronic attenuators and equalisers are in use.

Although it is possible to carry out a rapid check of equalisation using the signals on the network, at some time it may be necessary to re-check the procedure using a sweep generator; this can interfere with the operation of the live network.

Level measurements on the primary distribution network should be carried out with a portable spectrum analyser or signal level meter using the signals on the network. On the final distribution network, well-

calibrated SLMs may be used. However, the measurements should involve, as a minimum, carriers at each end and the middle of the operating frequency range, to check equalisation.

RF amplifiers, which have been repaired in the workshop, will need to have their frequency response and their distortion characteristics checked. Test equipment for this type of calibration work comprises network analysers and high grade spectrum analysers as well as carrier generators with appropriately low levels of inherent distortion.

1.3.3.1 Sweep Measurements

Sweep measurement is a non-intrusive frequency response measurement of the network and equipment. Test equipment is installed at the headend and a field unit is taken to the part of the network under test. This will display the response of the network either in the forward or return path, allowing for checking or adjusting values of equalisers, gain etc. The sweep responses can normally be stored for reference purposes.

It is claimed that up to 80% of faults, on both analogue and digital signals, can be found by sweep testing.

1.3.3.2 RF Leakage and Ingress (EMC Compatibility)

Cable operators' franchise licences require them to ensure that their networks do not contravene any regulations regarding interference/radiation from their networks to any authorised users of the RF spectrum.

It is also important that users of the spectrum do not themselves cause interference on the cable networks. This is not a matter of regulation but of customer satisfaction with the service.

Technicians must therefore be conversant with techniques for monitoring the Electromagnetic Compatibility (EMC) of the systems and where problems occur, which are likely to lead to ingress or egress of RF interference, to make the necessary repairs. Most cable operators will have installed a test carrier, with distinctive modulation, at the headend. Suitable "sniffer" equipment will have been provided to service and network technicians, and these will alert them if the level of RF leakage is excessive, as they carry out their normal day to day activities around the network. These incidences of high level leakage, if their causes are not immediately apparent and can be rectified, should be reported so that properly equipped staff can attend to investigate and make repairs. The most common cause of high leakage is poorly made of, or not correctly tightened, connectors on coaxial cables.

1.3.3.3 Digital Signal Measurements (SNR, BER and MER)

The advent of digital TV and distribution of data signals has made it necessary to introduce measurement techniques more appropriate to the assessment of digital signal quality. In analogue transmission it has become standard practice to measure the effects of noise impairments in terms of carrier to noise ratio (CNR). Digital signals share a carrier among a multiplex of signals and it is therefore more appropriate to refer to the "Modulation Error Ratio" or MER. MER is a combined figure of merit which includes carrier to noise and distortion.

For correct reception of a digital transmission we are concerned with ensuring that the bits in the stream of information are received correctly. Measurements to establish how many bits are received incorrectly (Bit Error Rate - BER) are therefore very important.

1.3.4 Telephony Faults

Faults on the telephony service in the final distribution network are inherently faults on the multipair cables from the Primary Rate Multiplexers (P-MUX) to the final distribution cabinets.

TDR equipment can be adapted to measure the location of faults on underground networks in difficult circumstances. The loop resistance of the pair of conductors can also give a good indication if the cable has been damaged. Specialised equipment is also available to detect the presence of inter-line shorts and other multipair cable defects which give rise to dialling errors and crosstalk i.e. the transfer of the signal from one pair on to another pair.

Some cable operators have contracts with the telephony hardware manufacturers that prohibit technicians from access to the cabinets housing the telephony equipment. All telephony faults, other than on the distribution network, are handled by resident manufacturer's technicians. Many cable operators however do have trained technicians to handle telephony faults at any level.

At the interface between the copper, analogue, distribution network and the fibre optic, digital, telephony service resides the P-MUX. Generally, these have printed circuits cards feeding a small number of lines, through which the dial tone, ringing tone and supply voltage is fed to each customer. Faults that do not affect more than one or two customers, in one location, are likely to be subscriber card replacement faults. In many cases the network management system, at the headend, will have identified many of the faults on the telephony network.

In addition, most modern telephony systems have very sophisticated status monitoring facilities built-in to the exchange equipment, and these can give a very good indication of outlying faults.

1.3.5 Fibre Optic Cable Measurements (see Section 3 for more details)

When one considers that a franchise operation with several hundred thousand homes can be sub-divided into hubs from which further fibre links feed optical nodes. Since the coaxial networks only feed 500 homes or less, it can be seen that the amount of fibre optic cable installed is very large indeed. It is not surprising therefore that network technicians will be very heavily involved in the maintenance of such networks.

In many cases the performance of the optical network is established by reference to the performance of the electrical signals that it carries as modulation of the laser light source.

Most modern optical fibre transmission systems have very sophisticated network management systems that can detect malfunction of most of the critical components.

1.3.5.1 Fibre Optic Cable Splicing and Termination

Generally, technicians will not be involved in the construction and commissioning of fibre optic networks. However the specialist skills of fibre optic cable splicing and termination should be acquired enabling them to perform the tasks of network fault repairs and minor modifications or additions to an existing system, which will normally be carried out in-house.

1.3.5.2 Optical Power Level Measurements

Checking optical power levels at optical transmitter outputs and optical receiver inputs can be important to establish that the optical equipment is performing correctly. An optical power level meter is used for these measurements. Optical receivers often have input signal-monitoring facilities, which may be faulty.

1.3.5.3 OTDR Measurements

In much the same way as time domain reflectometry has been used for fault location on copper cables, Optical Time Domain Reflectometers (OTDR) are used to find faults and reflections on optical fibre networks. These are ideal for identifying optical fibre faults and measure both the magnitude of the fault and the distance along the fibre cable.