INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.47

(10/2000)

SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Access facilities using hybrid fibre/copper networks

ITU-T Recommendation L.47

(Formerly CCITT Recommendation)

ITU-T Recommendation L.47

Access facilities using hybrid fibre/copper networks

Summary

This Recommendation gives information and guidelines about access facilities using HFC ("Hybrid Fibre/Copper") networks.

HFC networks are necessary for the future introduction of multimedia services with several broadband applications. HFC networks offer more chances of use as only pure networks for telecommunication or for CATV (Cable Television) distribution. Additional services as Pay-TV, Pay-per-View, Video-on Demand, home-banking, -working, -shopping and Internet access can be offered by means of these networks.

HFC networks represent also a step in the evolution process to GII (Global Information Infrastructure), that means a connection between CATV, telecommunications, data and mobile networks.

Appendix II provides examples of HFC networks.

Source

ITU-T Recommendation L.47 was prepared by ITU-T Study Group 6 (1997-2000) and approved by the World Telecommunication Standardization Assembly (Montreal, 27 September – 6 October 2000).

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

		Page
1	Scope	1
2	Fundamental types of hybrid fibre/copper networks	1
3	Physical elements of hybrid fibre/copper networks	2
3.1	Optical elements	2
	3.1.1 Optical cables	2
	3.1.2 Optical connectors	2
	3.1.3 Optical amplifiers	2
	3.1.4 Optical splitters	2
3.2	Electrical and copper elements	2
	3.2.1 HFC-S networks	2
	3.2.2 HFC-C networks	3
4	Installation	4
4.1	HFC-S networks	4
4.2	HFC-C networks	4
	4.2.1 Coaxial cables	4
	4.2.2 Cabinets	4
	4.2.3 Indoor installation	5
Appendix I – Questionnaire on Question 13/6 Access facilities using hybrid fibre/copper networks		5
I.1	Introduction	5
I.2	Topology	5
I.3	Cable construction	6
I.4	Components for CATV networks	6
I.5	Cable installation	7
I.6	Cabinet installation	7
Appendix II – Italian experience on HFC-C networks		8
II.1	Introduction	8
II.2	The HFC-C project	8
II.3	Network infrastructure for Italy	10
II.4	Coaxial network design	13
II.5	Evolution towards all optical networks	14
Appendix III – Indonesia's experience on HFC-C networks Access facilities using hybrid fibre/copper networks		15
III.1	Introduction	15
III.2	Background	15

Page

III.3	Network topology	15
	III.3.1 Transport network topology	15
	III.3.2 Access network topology	16
	III.3.3 Coaxial network topology	16
III.4	Cable construction	17
	III.4.1 Optical cabling	17
	III.4.2 Coaxial cabling	17
III.5	Bandwidth allocation	18
III.6	System configuration	18
	III.6.1 Headend	19
	III.6.2 Distribution hub	19
	III.6.3 Fibre node	20
	III.6.4 Amplifier (active component)	20
	III.6.5 Passive component	20
III.7	Powering system	21
	III.7.1 Powering system in coaxial cable	21
III.8	Outside plant (OSP)	21
	III.8.1 Pole	21
	III.8.2 Cabinet	22
III.9	Standardization	22
III.10	Coaxial network planning tool	22
III.11	Component for coaxial HFC-C networks	23
III.12	Legend	23

ITU-T Recommendation L.47

Access facilities using hybrid fibre/copper networks

1 Scope

This Recommendation:

- gives general information on the fundamental types of hybrid fibre/copper networks;
- describes the most important physical elements of HFC networks apart from transmission equipment;
- gives general information and guidelines for the installation of HFC networks.

2 Fundamental types of hybrid fibre/copper networks

Very different HFC network topologies can be considered, according to different Administrations' and private operators' requirements, different country or regional situations, different provided multimedia services. Moreover, HFC networks can be based on already existing telephone networks, both for the fibre and for the copper part of the network. However, the following general considerations can be applied to all the HFC network types.

An HFC network can be thought as composed of two main sections:

- First section: the "Transport Network" where the services are generated and delivered (at a national, regional or local level) up to main distribution points. The extension of the Transport Network can be huge. The physical transmission medium is the optical fibre.
- Second section: the "Access Network" where the final users are connected (at a local level) to the main distribution points. The extension of the Access Network is typically limited to a few kms in length. The bearer used in the first part of the Access Network is the optical fibre. The physical transmission medium of the last portion of the Access Network up to the users can be the symmetrical copper pair ("HFC-S" networks) or the coaxial copper/aluminium pair ("HFC-C" networks).

Typically, HFC-S networks are directly derived from traditional telephone copper access networks. The evolution towards new services can be achieved by means of particular data compression (JPEG, MPEG for instance) and transmission (HDSL, ADSL, VDSL for instance) techniques on the existing symmetrical pair cables. It is worth noticing that HFC-S type identifies a wide set of very different network solutions, according to the level of the optical fibre penetration into the Access Network and to the network topology. So, for instance, HFC-S type ranges from a simple point-to-point ADSL copper link up to FTTB ("Fibre To The Building") point-to-multipoint PON architectures.

The term HFC-C identifies a more restricted set of network solutions. HFC-C networks typically entail the installation of new active and passive coaxial components in the last portion of the Access Network, even if a simple update of an already existing HFC-C unidirectional network towards interactive services is considered. New HFC-C networks can offer up to 1 GHz bandwidth for CATV broadcast transmission and other broadband multimedia services.

It should be taken into account that:

- a study of economic factors, of already existing telecommunication networks, of present and future service requirements, of rules and regulations in each region should be carried out in order to decide between a HFC-S and a HFC-C type network;

- already existing infrastructures and ad hoc technical solutions should be used wherever possible in order to limit the environmental impact of the new HFC network, especially for the HFC-C network type.

3 Physical elements of hybrid fibre/copper networks

3.1 Optical elements

3.1.1 Optical cables

Both HFC-S and HFC-C networks make use of single-mode optical fibre cables in the Transport and in the Access Network.

It should be taken into account that:

- ITU-T G.652, G.653, G.654 or G.655 single-mode optical fibre should be used in the Transport Network. ITU-T G.652 or G.655 single-mode optical fibre are used in the Access Network;
- suitable studies have to be carried out in order to dimension the proper Access Network optical cable capacity: from 100 up to 1000 optical fibre cable capacities have been reported.

3.1.2 Optical connectors

Any standard (IEC) connector can be used in the Transport and in the Access Network.

In the case of analogue CATV transmission, the return loss of optical connectors needs to be carefully considered in order to meet the system requirements.

3.1.3 Optical amplifiers

Optical amplifiers are used both in the Transport and in the Access Network. The use of optical amplifiers as boosters can be associated with tree-type optical network topologies and with the use of optical splitters.

3.1.4 Optical splitters

In HFC networks, optical splitters are typically used in tree-type optical network topologies together with optical amplifiers in order to expand the distribution area of a single optical transmitter. In HFC-S PON (Passive Optical Networks) architectures optical splitters are used as branching devices both in central offices and in the field. From 1:2 up to 1:32 splitting ratios have been reported.

3.2 Electrical and copper elements

3.2.1 HFC-S networks

3.2.1.1 Symmetrical pairs cables

From 0.4 mm to 0.64 mm wire diameter symmetrical pairs copper cables are typically used in the Access Network for 100 up to 1500 metres typical distances. From 10 up to 3000 symmetrical pairs cable capacities are used, according to different Access Network requirements.

Studies and characterizations should be carried out on the already existing symmetrical pair copper cables in order to verify that they can support the chosen xDSL transmission technique. Refer also to the G.990-series Recommendations.

3.2.2 HFC-C networks

3.2.2.1 Coaxial cables

- *Coax-trunk cable*

  1 GHz bandwidth, 12.7 mm (1/2 inch) or 19.05 mm (3/4 inch) outer conductor diameter, 75 ohm impedance coax-trunk cables are used in HFC-C Access Networks from 100 up to 500 metres typical link length between the launch and the last amplifier.

- *Coax-drop cable*

  1 GHz bandwidth, RG-11 and RG-6 standard types, 75 ohm impedance coax-drop cables are used in HFC-C Access Networks from 50 up to 150 metres typical link length between the last amplifier and the coaxial network termination.

  Wherever possible, cables should be chosen in order to limit the number of coaxial amplifiers. In spite of their low mechanical flexibility (which can constitute a problem during installation), 19.05 mm (3/4 inch) outer conductor diameter coax-trunk cables offer very good attenuation performance.

3.2.2.2 Coaxial connectors

The 15.825 mm (5/8 inch) and F type coaxial connectors are typically used for cable terminations. However, many different connector versions can be used according to the different coaxial cables versions, dimensions and applications.

Careful choice of connectors should be made in order to prevent in-field problems due to environmental causes (such as temperature, humidity, vibrations, etc.). In most of the cases, coaxial connectors should be protected by means of a shrinkable plastic sheath.

3.2.2.3 Coaxial splitters

Coaxial splitters are typically used on the output ports of coaxial amplifiers (especially in front of launch amplifier) in order to subdivide the electrical signal on the different coax-trunk cables of the HFC-C network. 1:2, 1:3 and 1:4 splitting ratios are common.

3.2.2.4 Coaxial taps

Coaxial taps are typically used on the output ports of the last amplifiers or for in-building coaxial distribution networks. Many types and versions are available on the market; 2, 4, 8 and 16 output ports coaxial taps are common.

3.2.2.5 Electro/optical converter and coaxial amplifiers

Electro/optical converters, launch amplifiers, line extenders and last amplifiers are used in HFC-C network respectively in order to transform the optical signal into an electrical one, to launch the electrical signal on the coaxial network, to amplify the electrical signal in the case of very long coaxial links (typically more than 500 metres), to amplify and to distribute the electrical signal to the final users area. The active tree-type coaxial network originated by a single electro/optical converter is usually designed in order to serve from 100 up to 500 users, by means of from 3 to 9 last amplifiers.

The use of line extenders should be limited to those cases of actual necessity.

3.2.2.6 Power supply

The coaxial portion of an HFC-C network is remotely powered from the electro/optical-launch amplifier cabinet by means of a properly dimensioned power supply (45-60 Vac, 10-15 A are typical values).

The power supply should be designed in order to limit the environmental impact (noise) in urban installation.

4 Installation

This clause gives general information and guidelines on some particular aspects of the installation of metallic cables forming a part of HFC-S and HFC-C networks. See L-series Recommendations for optical fibre cable installation practices.

4.1 HFC-S networks

HFC-S type identifies a wide set of very different network solutions, according to the level of the optical fibre penetration into the Access Network and to the network topology. So, installation procedures can involve a simple ADSL modem installation up to the in-field layering of new optical cables and ONU (Optical Network Unit) cabinets in the Access Network, with a huge variety of situations and potential problems.

It should be taken into account that:

– existing infrastructures should be used wherever possible (ducts, manholes, etc.);

– proper technical solutions should be studied in order to limit the environmental impact of new cabinets and new cable installation in terms of civil works, urban soil occupation, visual effect;

– proper technical solutions should be studied in order to ensure the reliability and the maintenance of the HFC-S network from the viewpoint of hardware and software;

– existing infrastructures should be studied as to how they could be reused in HFC-S networks.

4.2 HFC-C networks

With respect to the HFC-S type, the HFC-C type identifies a more restricted set of network solutions. Some information and guidelines are given in the following on different HFC-C network elements.

4.2.1 Coaxial cables

Coax-trunk cables are typically less flexible and more cumbersome than, for instance, optical cables. Due to these reasons, ad hoc manholes, ducts and installation procedures have to be used in order to avoid any cable damage.

It should be taken into account that:

- suitable pulling, handling and layering procedures should be observed in order to avoid cable kinks according to the cable recommended curvature radius;
- for in-duct installation, suitable ducts and manholes should be used for trunk cables. From 36 up to 63 mm diameter ducts have been reported for a single trunk cable installation;
- for aerial or wall installation suitable cable accessories (holders, steel wires, lashes, etc.) should be used to support and fix the cable.

4.2.2 Cabinets

The high number of outside plant cabinets for active equipment is a typical characteristic of HFC-C networks.

Suitable cabinet design should be carried out in order to ensure the operative range of active equipment according to their characteristics and to the environmental conditions (temperature, humidity, vibrations).

Proper technical solutions should be studied in order to limit the environmental impact of cabinets in urban areas. Different cabinet versions for on-ground, underground and aerial installations should be studied in order to meet particular installation requirements.

4.2.3 Indoor installation

It should be noted that the installation of equipment for HFC-C networks in the customer's property could present problems in terms of obtaining permission of the user.

It should be taken into account that:

- existing building infrastructure should be used wherever possible;
- additional infrastructure for drop cable installation should be avoided wherever possible;
- cables and accessories have to satisfy country and regional regulations on fire protection requirements.

APPENDIX I

Questionnaire on Question 13/6
Access facilities using hybrid fibre/copper networks

I.1 Introduction

This appendix summarizes the main results of the Questionnaire on Access Facilities Using Hybrid Fibre/Copper Networks. Five countries (Italy, Japan, Spain, Sweden and United Kingdom) answered to the questionnaire. A comparative detailed report of the answers of each country is given in this appendix.

I.2 Topology

I.2.1 General description of the network: The network provider is a private operator; the network has a star configuration or a point-to-multipoint or ring. It is extended to regions or countries. Generally all the types of listed cables, and particularly copper cables in Japan and Sweden, are used.

Hybrid technology is used.

The transmission range frequency plan varies considerably. It is 54-862 MHz (downstream) and 5-40 MHz (upstream) in Italy, 50 Mbit/s bidirectional with TDMA in Japan, 86-862 MHz downstream and 5-55 MHz upstream in Spain. It is 54 (70,85)-860 MHz downstream and 5-25(50,60) MHz upstream in Sweden, 10-65 MHz upstream and 85-860 MHz downstream in the United Kingdom.

The transmission is both analogic and digital. Generally the provided services are CATV and interactive services.

I.2.2 Transport network topology: The used topology is a star or ring configuration and the transmission technology is SDH. The transmission medium is optic fibres and the cable type is in-duct.

I.2.3 Access network: The topology is a star one or point-to-multipoint. The transmission medium is optic fibres and the cable type is an in-duct one.

I.2.4 Subscriber access: The topology is tree.

The transmission media are copper pairs, coaxial cable and optical fibres. The cable type is in-duct and aerial. The number of consumers supplied between last amplifier and NT varies from 60-70 (I) to 30-70 (SWE), 25 (UK). Spain reported 350 passed homes per distribution area.

I.2.5 Inside building network: The topology is point-to-point or point-to-multipoint. The transmission media are symmetrical copper pairs, and/or coaxial pairs and the installation is in ducts and wall mounted.

I.3 Cable construction

I.3.1 Transport network: The type of cable installation is in-duct and/or aerial. The optical fibre utilized is a SM one. The optical fibre cable sheath design is a PKH9E, PKH5E (E: polyethylene inner sheath, K: aramidic yarn, H9: corrugated steel tape, E: polyethylene outer sheath, H5: aluminium tape) a polyethylene or a metalfree. The optical fibre cable core design is mainly loose tube or slotted core stranded filled cables. The number of fibres per cable is 12 to 60 (I), up to 300 (JP), between 16 and 128 (ES), 24F, 48F, 96F (SWE), 8 (UK).

I.3.2 Access network: The cable type is normally an induct cable and the optical fibre cable type is a SM fibre while the optical fibre cable sheath design is a PKH9E, PKH5E, a polyethylene or metalfree. The optical fibre cable core design is a loose tube or a slotted core stranded filled one.

The number of fibres is 12-60 (I), up to 1000 (JP), between 2 and 8 per tube, between 16 and 128 per cable (ES), 4-24(4-fibre ribbons) (SWE), 8 (UK).

I.3.3 Subscriber access. The cable type is duct or aerial; the optical fibre cable type is with SM fibres; the optical fibre cable sheath design is a EKH9E, a metalfree or a polyethylene. The optical fibre cable core design is generally a loose tube or a slotted one with fibre ribbons, and the number of fibres is 5 ribbons per slot (20-40 fibres per slot) (I), up to 1000 cores slotted rods and 4 or 8 optical fibres ribbons (JP), 4F-24F (SWE), 8 up to 96 (UK).

In Japan there is no coaxial cable utilized. Elsewhere coaxial trunk and drop cables are used.

The conductor diameter of the trunk cables varies from 3.15 to 13.7 mm or 2.64 to 11.5 mm. The attenuation is between 4.7 and 5.8 dB/100 m.

Drop cables usually have a conduct diameter between 1.02 and 4.6 mm, and an attenuation of 14.9 or 9.9 dB/100 m at 450 MHz.

In Italy, trunk cables usually have aluminium welded tape without overlapping. Drop cables have two layer outer conductors: the first is a double aluminium tape outer, a polyester sandwich, the second layer has a tinned copper braid. Sometimes copper cables with overlapping are used (UK).

I.3.4 Inside building (installation) cables: Where in-building optical cables are used (JP, ES, SWE), SM fibres are used. RG-6 and RG-11 standard coaxial drop cables are used. The standard cable length between NT and TV set is between 10 and 20 metres.

I.4 Components for CATV networks

I.4.1 Optical components for CATV networks: The optical transmitter uses SM fibres at 1550 nm with a bandwidth up to 862 MHz with about 20 analogue and 70 digital TV video and audio channels (I); SM fibres, 1310 nm and 1550 nm and a band up to 862 MHz (ES); 1310 nm or 1550 nm (SWE); SM fibres, 1310 nm and up to 862 MHz (UK).

The optical amplifiers use SM fibres in the third window in every country.

The optical receivers use SM fibres in the third and second window with a bandwidth up to 862 MHz.

The fibre splitters use SM fibres; the wavelengths are at 1310 nm and 1550 nm; in the table below the splitting ratios adopted are reported.

Italy	Spain	Sweden	United Kingdom
2-4-8-12 outputs	1x8, 1x16, 1x32, 2x4, 2x8, 2x16, 2x32	1x2, 1x4, 1x8, 1x16, 1x32	1x3, 1x4, 1x8 only at 1310 nm

I.4.2 Coaxial components for CATV networks: The connectors used for drop cables are type F with a return loss ≥ 30 dB, type 5/8, for trunk cables with a return loss ≥ 30 dB (I). In Spain the type F is also used together with 5/8-24 or EN60169-24, the return loss is ≥ 30 dB. In Sweden there are problems with poor connectors in the CATV network; the standards adopted are EN50083-2 and EN50083-4. In the United Kingdom type F, 5/8 and M14 coaxial connectors are used.

Coaxial splitters for trunk cables have splitting ratios of 2, 3 or 4 typically.

Directional couplers have splitting ratios of 2, 8, 12.

Taps have a number of ports that vary from 2 to 16 with an insertion loss that varies consequently between 5.2 and 24 dB.

Regarding the active coaxial components there are usually three amplifiers: launch, extender and last amplifier.

I.5 Cable installation

I.5.1 Cable type: Duct, aerial and inside building installation (I), (JP), (ES), (UK), for optical, coaxial and symmetrical copper pairs cables.

I.5.2 Installation methods: They include typically pulling. The blowing technique is also adopted (ES, UK) for optical cables.

I.5.3 Installation lengths: They vary with the country.

In Italy, the installation length is about 1-3 km for in-duct optical cables; optical cables are not used inside buildings. The installation length reaches the 500 m maximum in in-duct coaxial cables, 100 m in inside building coaxial drop cables. Symmetrical copper pairs cables reach 500 m in length typically in duct.

In Japan there are duct cables with an average length of 1 km and aerial cables of around 500 m. Inside building cables reach an average length of 300 m.

In Spain installation length is between 1 and 2 km.

In Sweden, cable length is normally about 2-4 km for optical cables, and 200-300 m for coaxial cables.

I.5.4 Method of aerial installation: The methods are different, depending on the type of the cable.

In Italy the methods are wrapping and lashing for optical cables, wall installation for coaxial cables and lashing for symmetrical copper pair cables. In the other countries the method usually adopted is the self-supporting one.

I.6 Cabinet installation

I.6.1 Use of the cabinet: A lot of cabinets are used for fibre nodes, line extenders, last amplifiers, splitters and outdoor taps in HFC-C networks.

I.6.2 Installation type: The places of installation are the road, aerial or inside building; then, depending on the possibilities, they can be: underground, curb, inside building, wall and flat roof.

The main characteristics of the cabinets are reported in the following table:

	Italy	Japan	Spain	Sweden	United Kingdom
Dimension in cm	– FN cabinets: 75x152x32 (curb)/168x87x83 (underground) – LE, LA cabinets: 75x124x32(curb)/ 90x35x40 (underground)/ 71x65x24 (in building) – Taps: 33x96x29(curb)/ 34x48x25, 33x52x30 (in building)	60x20x10	different types	70x90x30	120x100x75
Material	Plastic	Metal	Plastic	Galvanized steel sheet	Metal

I.6.3 The thermal compensation is passive.

I.6.4 Internal elements: They depend on the type of the cabinet. They can be optical fibres, coaxial and copper pairs, with a configuration that can be rigid or flexible, mainly depending on the type of the cabinet.

APPENDIX II

Italian experience on HFC-C networks[1]

II.1 Introduction

In 1995, Telecom Italia chose a Hybrid Fibre Coax (HFC-C) architecture for the distribution of broadband and multimedia services in the Italian access network according to a Sub-Carrier Multiplexing (SCM) Passband transmission technique.

HFC-C network design and construction were particularly complex in Italy, due to Telecom Italia's high quality level requirements and to the variety of urban and administrative situations.

This appendix summarizes the field experiences and the most important particular solutions developed for the HFC-C project, from the designer's and the installer's points of view.

II.2 The HFC-C project

Recently, growing availability of broadband services, higher quality requirements for traditional services and the liberalization of the European telecommunication market, have forced operators towards new access network technologies.

In the case of Telecom Italia, the HFC-C project had the target to gradually develop a broadband network platform according to the following three phases:

- Phase 1: analogue video services distribution and preparation for digital video transmission;
- Phase 2: video distribution and multimedia interactive on-line services;
- Phase 3: video distribution and multimedia interactive services with integration of traditional narrow-band services.

---

[1] BOTTANELLI (M.), COTTINO (E.): "Building Italian Hfc Broadband Distribution Network: Field experiences and special installation solutions, *46th International Wire and Cable Symposium*, Philadelphia (USA) – 17-20 November 1997.

In the technical solution for the HFC-C project phase 1 (Sub-Carrier Multiplexing Passband transmission) analogue and digital signals are multiplexed by means of suitably spaced radio frequency (RF) sub-carriers: the resulting signal modules an optical carrier which is transmitted to the network peripheral nodes.

The reference architecture for the HFC-C project phase 1 is sketched in Figure II.1, according to the following node classification:

- *Head End (HE)*: the centre where different video signal sources are processed and organized to become available on the network;
- *Distribution Node (DN)*: the network entry point for channels coming from different HEs. In the DN, video signals are put on the available transmission band by means of frequency multiplexing. A DN typically serves a metropolitan area and its suburbs;
- *Local Node (LN)*: this network node receives signals from the DN and parts them on the urban distribution area FNs;
- *Fibre Node (FN)*: this network node converts the optical signal into an electric one and distributes it by means of a tree-like coaxial network. An FN typically serves a maximum distribution area of 400 homes;
- *Last Amplifier (LA)*: the last amplification point before distribution to the customers. In the case of low signal levels (very broadened customer area) it is often necessary to add a further amplification point on the trunk network between FN and LA ("Line Amplifier" or "Line Extenders").

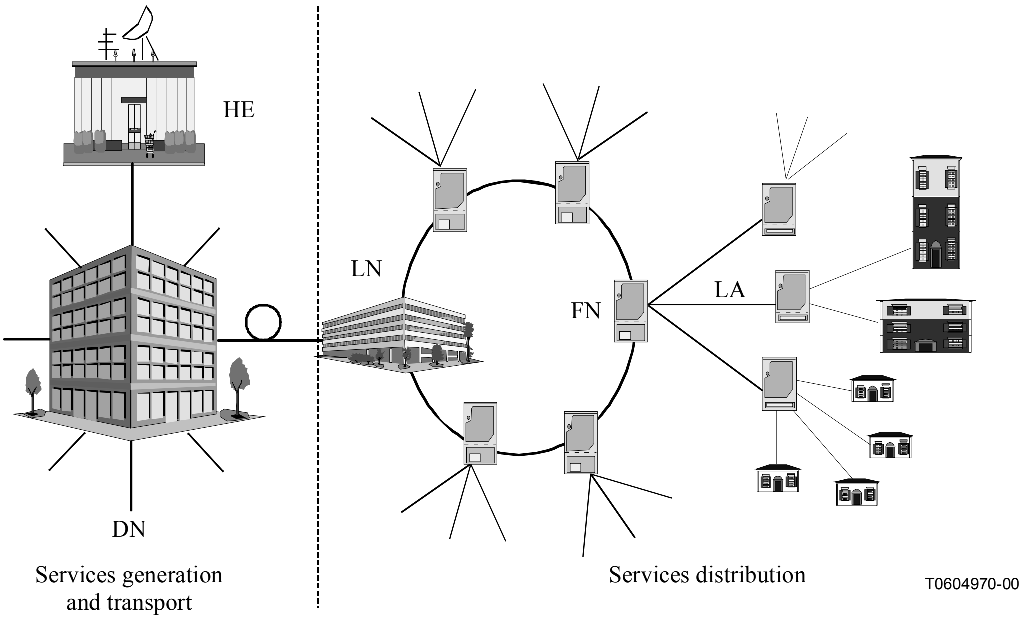


Figure II.1/L.47 – HFC-C architecture for the project phase 1

From HE to DN channels are transported by means of SDH 34 Mbit/sec links; from DN to LN analogue transmission is carried out by means of optical regional network; from LN to FN optical fibres of the primary distribution network are used; finally, from FN to LA and up to the customer NT ("Network Termination") transmission is carried out by means of a tree-like amplified coaxial network for 500 metres typical maximum link lengths.

The coaxial part of the network limits the available bandwidth to 1 GHz according to the following targets:

- from 5 up to 30 MHz for network control signalling and interactive services upstream transmission;
- from 54 up to 470 MHz for analogue video distribution;
- from 470 up to 862 MHz for digital video distribution, telephony and data transmission;
- from 862 up to 1000 MHz, the band is available for future applications.

II.3 Network infrastructure for Italy

Different problems had to be solved in order to implement the above-described HFC-C architecture in the field, because of both Telecom Italia requirements and the different urban and administrative situations in Italy.

Table II.1 summarizes in very general terms the three basic cable installation techniques for the access network according to their cost, reliability and flexibility characteristics. As in the past, Telecom Italia chose cable in-duct installation with operation, connection, and distribution manholes. This is the most expensive solution but the most reliable and flexible too, considering Italy's needs and future evolution of the network.

Table II.1/L.47 – Cable installation techniques

	Cost	**Reliability**	**Flexibility**
Aerial	Low	Low	Medium
Buried	Medium	Medium	Low
Duct	High	High	High

Less expensive HFC-C architectures can be designed for simplified contexts by means of the following solutions (see Table II.2):

Table II.2/L.47 – Solutions for less expensive HFC-C networks

• Frequent wall and pole installation
• Low depth cable duct installation (30 cm)
• More than one cable in the same duct
• Limited cabinet numbers and typology
• Different services (HFC-C+FTTC) in the same cabinet
• Twin cables (coax and t.p.) for customer connection

In every case, an HFC-C architecture automatically implies the presence of active elements in the field. Figure II.2 summarizes coaxial components according to their cabinet or their housing in the network.

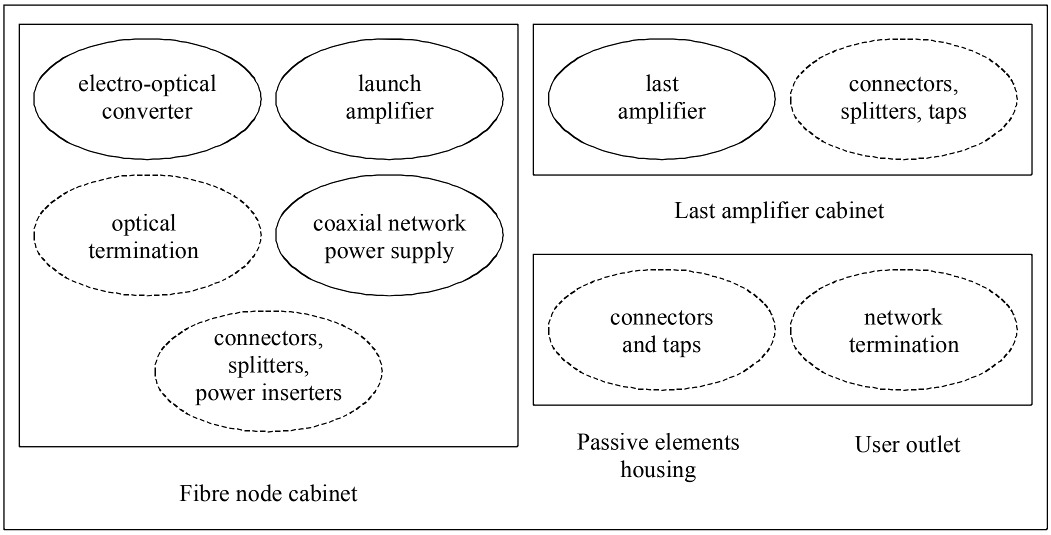


Figure II.2/L.47 – Coaxial network elements and cabinets

Among them, the ones circled with a continuous line are active, and may dissipate from 15-35 Watts (RF amplifiers) up to 100-150 Watts (FN coaxial network power supply).

FN and LA cabinets are commonly installed on curbs, while passive component housings can be installed both on curbs and in customer buildings. The following simple estimate can give an idea of the HFC-C network environmental impact: in the circular area around a FN, there are typically 6 LA cabinets and about 20 passive component housings.

For these reasons, the physical construction of such a network had to face a lot of limitations, according to the ground morphology, customer distribution, administration requirements, the presence of historical monuments, and so on.

Limitations and requirements might change according to different cities in a very dramatic way, so that what was requested in some areas was strictly forbidden in others. Table II.3 summarizes some of the typical HFC-C network different installation requirements or situations for Italy.

Table II.3/L.47 – HFC-C network different installation requirements

• Underground LA installation only
• Forbidden underground LA installation
• Built-in wall LA cabinets
• On curb excavations only
• On grade excavations only
• Forbidden parallel excavations
• Crossing excavations near cross-roads only
• Use of no-dig techniques when possible
• Air installation highly recommended (Venice)
• Frequent use of line amplifier

In order to meet so many different requirements, different solutions concerning installation techniques and cabinet types and locations were developed and experimented. Examples of these solutions are listed in the following points:

- Directional drilling (Figure II.3), air, pole, and wall installation techniques were adopted to limit HFC-C network environmental impact.

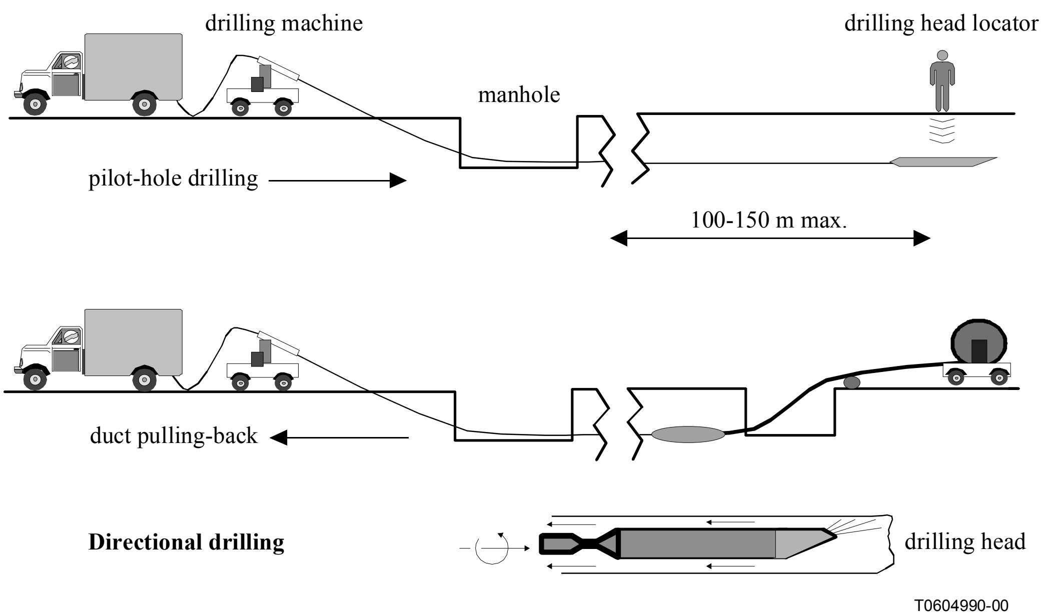


Figure II.3/L.47 – Scheme of the directional drilling technique

- On curb FN and LA cabinets were derived from traditional twisted pairs distribution cabinets by means of careful calculation and proper design of heat dissipation (more than 300 Watt) louvres for natural convection.
- 300 twisted pairs Telecom Italia old cabinet modules were adapted for in-building installation of a LA and two taps.
- Underground waterproof sheet moulding compound LA cabinet (Figure II.4) was developed for installation into manholes.

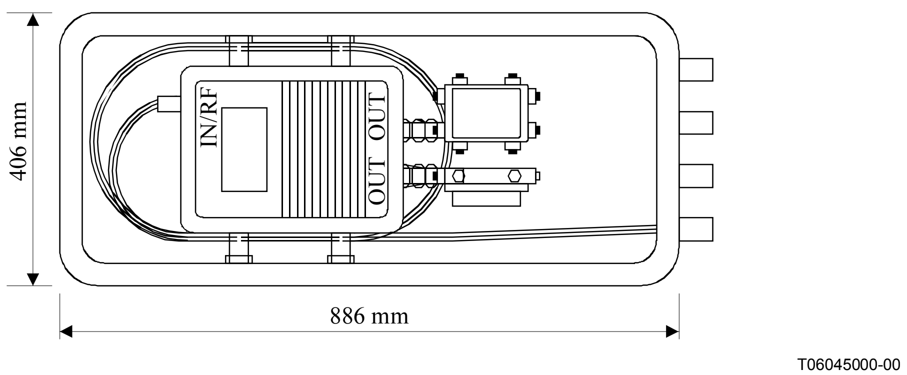


Figure II.4/L.47 – Underground LA cabinet sketch

- Finally, a whole FN underground cabinet was developed.

II.4 Coaxial network design

The optimization of the HFC-C network infrastructure with reference to field requirements is one of the basic coaxial network design targets. This activity proceeds according to the following different steps:

- broadband connections definition;
- walk-in;
- walk-out;
- catchment areas definition;
- RF design;
- civil design;
- bill of materials;
- drawing.

In the Telecom Italia HFC-C network design reference guide, customer premises were classified according to broadband connection requirements as summarized in Table II.4.

This first classification is followed by a detailed analysis of the horizontal and vertical premises layout ("walk-in maps") in the considered area. Moreover, by means of the so-called "walk-out maps", the network designer is informed of building entrances, suitable places for cables and cabinets installation, and of already existing infrastructures.

Table II.4/L.47 – Customer premises classification

Type	Description	Number of BB lines
A	apartments, offices, shops	1
B	commercial centres, schools, < 20 rooms hotels/residences	4
C1	20-80 rooms hotels/residences	40 (1 LA)
C2	81-150 rooms hotels/residences	80 (2 LA)
D1	> 400 circuits business customers	1 FN
D2	101-400 circuits business customers	1 FN
D3	51-100 circuits business customers	as B or C
D4	> 150 rooms hotels/residences	1 FN

The RF coaxial network design is then usually obtained by means of an automatic CAD (Computer Aided Design) system according to a typical bottom-up approach, proceeding from LA areas definition ("Catchment areas definition") up to FN. On the basis of a highly detailed RF component database, the designer can easily dimension all parts of the coaxial network in order to ensure at least 12 dBmV electrical signal level at the customer network termination.

15.8 mm (.625 in.) and 19.1 mm (.750 in.) aluminium based trunk cables are used to connect FN to LAs and LAs to taps, while type 6 and type 11 drop cables are used for customer premises cabling. The availability of different cable types and attenuations allows minimizing the number of RF line amplifiers in the network.

The civil design immediately follows the RF one: the CAD operator has to choose cabinets, manholes, and ducts typology and locations, exploiting already existing infrastructures as much as possible.

Finally, the CAD system can automatically extract from the network design the bill of materials and draw the requested documentation (coaxial and civil planimetries).

II.5 Evolution towards all optical networks

With reference to future developments, it is worth considering the following consequences of the project:

- introduction of broadband services transmission technologies in the Italian access network;
- arrangement of infrastructures for a possible future network expansion towards new architecture types (HFC-S for instance).

While the first aspect is directly related to the project mission, the second one often risks to be underestimated.

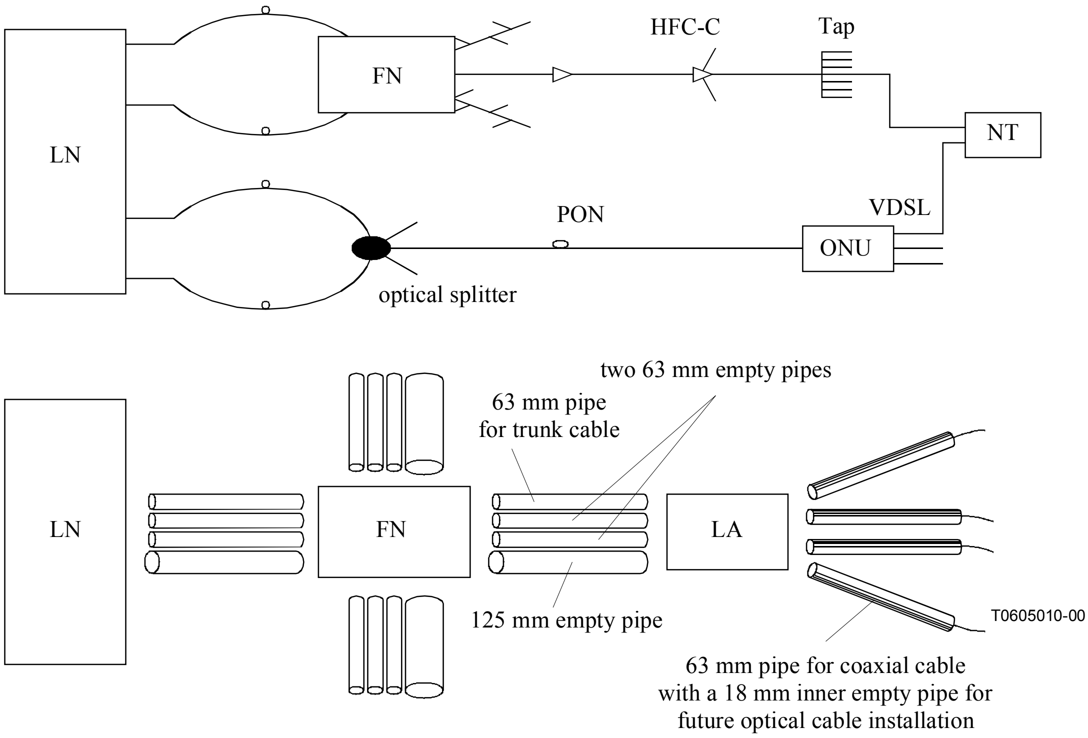


Figure II.5/L.47 – Evolution towards all optical networks: HFTTB

Figure II.5 illustrates an example of the project evolution potentiality (Hybrid Fibre To The Building architecture). Here the HFC-C infrastructure is compared to a possible future passive optical network (PON) experimentation, as a first step towards all services integration.

HFC-C infrastructure was in fact already arranged to support a passive optical network, with optical splitters located near FN cabinets. From FN to LA cabinets and for every HFC-C network directrix, two 63 mm and one 125 mm empty pipes were prepared for future applications. Moreover, from LA to customer premises, every 63 mm pipe for coaxial cable was equipped with an inner 18 mm empty pipe for future optical cable installation.

With reference to Figure II.5, from LN to FN, HFC-C network and PON share the same optical cable ring on different fibres; from FN to customer premises they lean on the same infrastructure; finally the two networks match at the user outlet. Broadband distribution services are transmitted on the HFC-C network; traditional and broadband interactive services might be integrated and transmitted on the PON.

APPENDIX III

Indonesia's experience on HFC-C networks
Access facilities using hybrid fibre/copper networks

III.1 Introduction

This appendix explains several technical and electrical specifications for HFC-C network implementation in Indonesia, which refers to the Questionnaire on Access Facilities Using Hybrid Fibre/Copper Networks for Question 13/6. Some tables and a legend are given for clear information.

III.2 Background

HFC-C was one alternative access network technology to support broadband services and interactive multimedia with several considerations. Strong reasons to implement HFC-C technology in Indonesia were such as:

- Optical network had been installed as backbone network, to connect between two exchanges. This network could be used for trunk network in HFC-C to connect Headend with Distribution Hub.
- Simple coaxial network was already available in several hotels that could be used for HFC-C applications.
- High potential demand for television distribution, Internet services, and interactive multimedia especially for real estate area, condominium, and hotels.
- HFC-C as "big pipe" for future bandwidth necessities and new technology in the future.

HFC-C offers several kinds of multimedia services and basic communications; some are:

- Telephony (POTS).
- Broadcast TV analogue.
- Broadcast TV digital.
- Fast Internet.
- On demand services: VOD (Video on Demand), MOD (Music on Demand), KOD (Karaoke on Demand).
- Interactive multimedia.

III.3 Network topology

III.3.1 Transport network topology

The topology used is a ring configuration and the transmission technology is SDH. The transmission medium is optic fibres and usually the cable installation is in duct system.

III.3.2 Access network topology

Demarcation area between transport network and access network is at the headend. The headend up to customer side is called access network (Figure III.1). The transmission medium from the headend up to fibre node use to optic fibres, and from the fibre node up to customer side use to coaxial network.

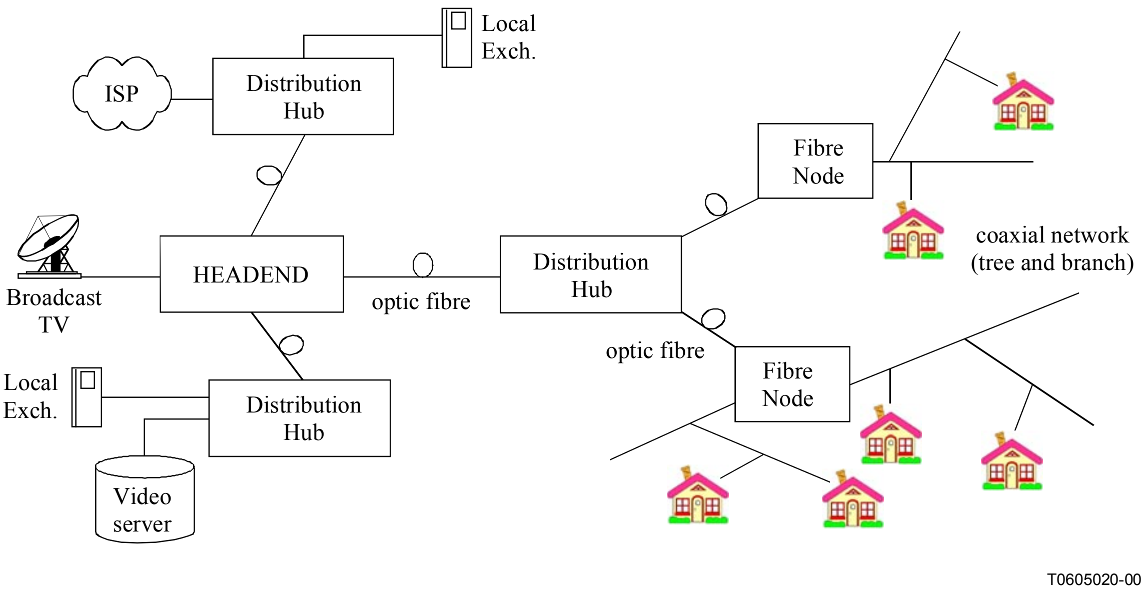


Figure III.1/L.47 – Access network topology

III.3.3 Coaxial network topology

The topology of coaxial networks is tree and branch (Figure III.2). The cable types are both aerial and duct system. Commonly, each fibre node supports about 500 homepass whereas capacities homepass each fibre node depends on the services that will be delivered to the customer.

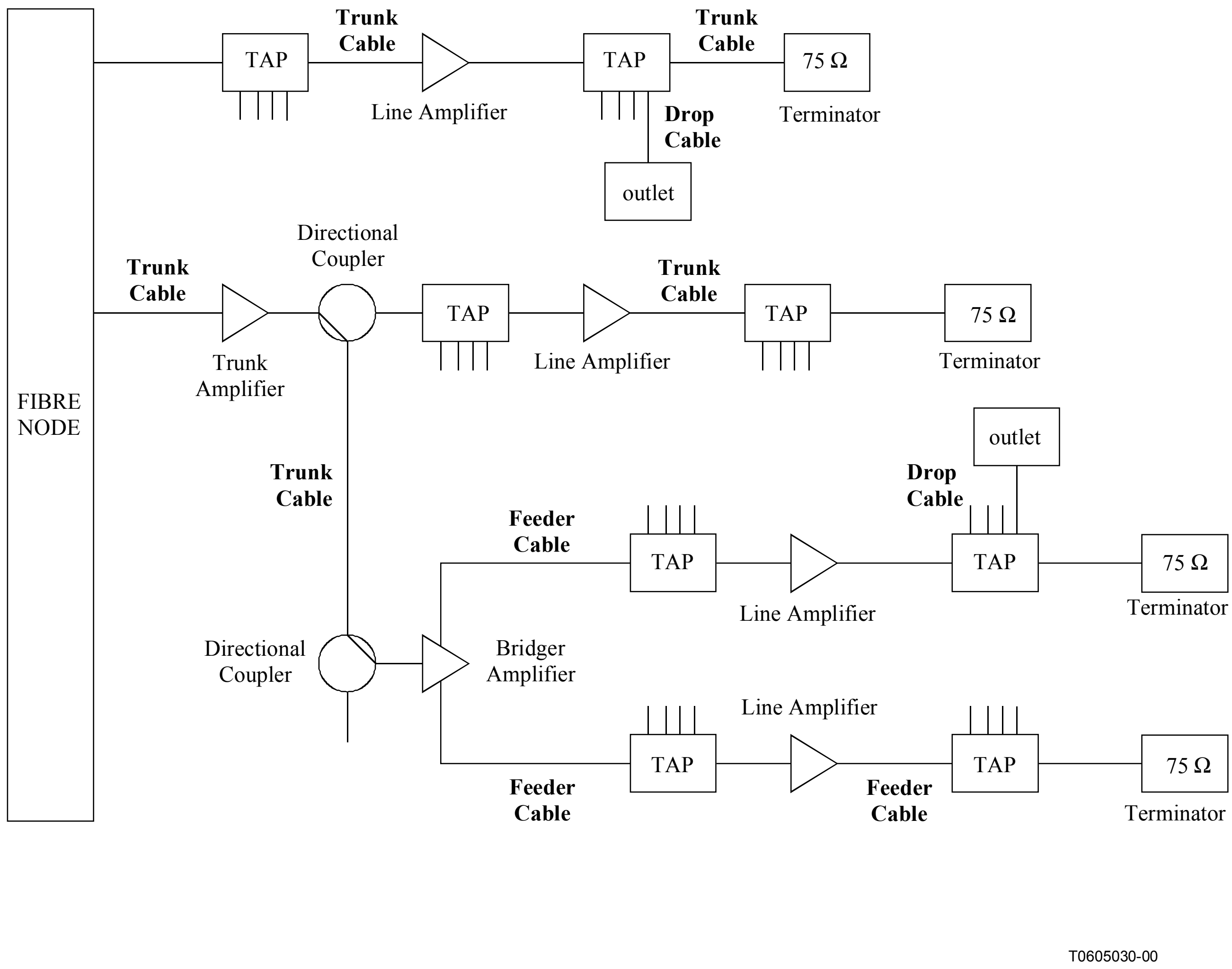


Figure III.2/L.47 – Coaxial network topology

III.4 Cable construction

III.4.1 Optical cabling

The optical transmitter uses single mode fibres at 1310 nm and 1550 nm. Cable specification is G.652. Distribution fibre network can be point-to-point and point-to-multipoint. For point-to-multipoint configuration the fibre is split by an optical passive splitter 1: n.

III.4.2 Coaxial cabling

Coaxial cable was divided into trunk/feeder cable and drop cable.

- Trunk/feeder cable that TELKOM recommended were cables with diameter of 0.500; 0.625; 0.750; 0.875 and 1.00 inch.
- For drop cable RG-6; RG-11 and RG-59 were recommended.

If we look at the cable's application function, the kind of coaxial cable was the same with other cable, it was divided into direct buried cable, duct cable and aerial cable. TELKOM did not recommend Siamese cable for double coaxial, but it was possible for the twisted pair built-in coaxial cable for powering purposes.

In the application, selection of the type of cable was usually determined by the condition of boundary area homepass. If the boundary for trunk/feeder network was very wide, we could choose a trunk/feeder cable with a large diameter, because that kind of cable had lower loss cable. For special conditions in the customer side, for example, the existence of so much noise and interference, it was better to use drop cable with double protections (quad shield or tri shield). Normally, the boundary for coaxial network was about 1 km^2 up to 2 km^2.

III.5 Bandwidth allocation

For the beginning of implementation of HFC-C, bandwidth allocation that was standardized by TELKOM was up to 862 MHz (see Figure III.3). It was possible to increase the bandwidth up to 1 GHz for the future services if needed. The same with upstream bandwidth that recommended up to 40 MHz, could be increased if there were additional services for upstream. The guardband between upstream and downstream was recommended to be 10 MHz.

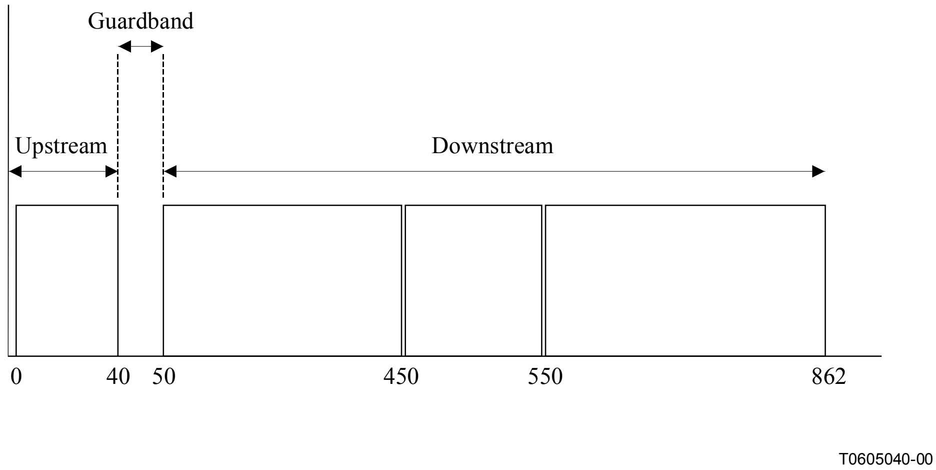


Figure III.3/L.47 – Bandwidth allocation for HFC-C system

- From 0 up to 40 MHz:
  For telephony, upstream data communication, control signal for VOD, and management signal.
- From 40 up to 50 MHz:
  Guardband between upstream and downstream.
- From 50 up to 450 MHz:
  For TV analogue broadcast and radio FM broadcast.
- From 450 up to 550 MHz:
  For TV digital broadcast (Pay per Channel, Pay per View and Near VOD).
- From 550 up to 862 MHz:
  For telephony, data communication, real VOD.

III.6 System configuration

Figure III.4 gives a common configuration of an HFC-C network. TELKOM recommended only one headend to the entire HFC-C network in one location. For example Jakarta, Bandung and Surabaya are big cities; TELKOM considered it ideal that there was only one headend in each city. The optical network from headend to distribution could reach about 30 km, also for the optical network to the fibre node. System configuration in the distribution hub depended on service provider arrangements. If the service provider just gave an Internet application, there was no need for cable telephony headend and video interactive headend in the distribution hub. The service provider just presented the cable data headend that connected to the ISP or data source service and gave a cable modem to the customer, without STB (Set Top Box). It was possible if in the network there was no distribution hub, just only the headend, or distribution hub and headend in one location and one system.

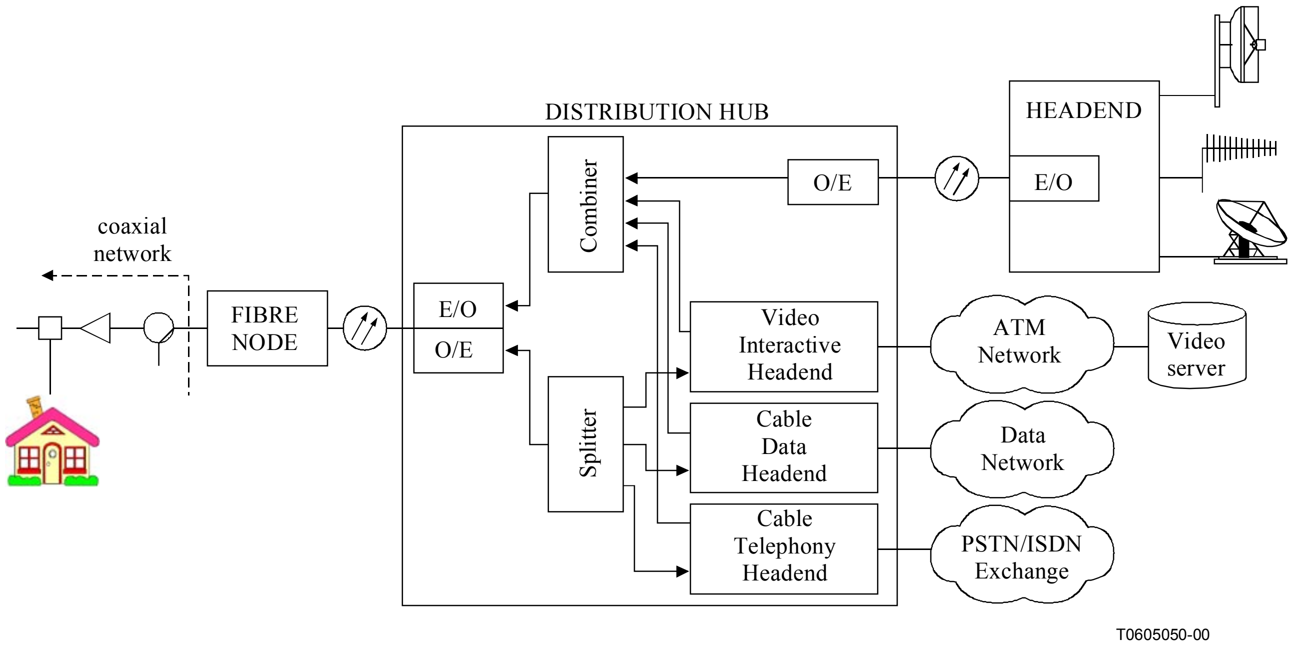


Figure III.4/L.47 – HFC-C system configuration

III.6.1 Headend

The headend had functioned as a centre of broadcast TV services, for both analogue and digital TV. For one HFC-C area services, TELKOM recommended one headend location for all customer/homepass. The headend would be connected to one or several distribution hubs. The service source for broadcast TV came from TV satellite, local TV (off air) and digital TV microwave terrestrial.

III.6.2 Distribution hub

The distribution hub combined broadcast TV services from the headend to other services depending on application in that area. Services could be VOD from one video server, Internet to connect to one ISP and telephony from the local exchange. The distribution hub could be implemented in several locations in the local exchange. It was also possible that the headend and distribution hub were in the same location (co-located). Usually the distribution hub used optical backbone/junction networks that were already used for connection between two exchanges. Almost all big cities in Indonesia had already used optical network as a junction connection.

Besides that, another consideration was access capability to ISP location and access to PBX or exchange location. Consideration whether TELKOM would act as only the network provider or become the service provider would change the global system configuration, especially whether the limit between network provider and service provider was in the distribution hub or started from opto-transceiver devices from combiner if TELKOM acted just as the network provider.

III.6.3 Fibre node

Fibre node as active component had a function to convert RF signal to optic signal or vice versa. Usually one fibre node was designed for about 500 up to 1000 homepass, depending on the kind of services that would be implemented and customer boundary/cluster.

The number of leg outputs from the fibre node should be a maximum of 3 legs of which each leg could be high-level output or low-level output. High-level output was usually used to cover big homepass that was very far from the fibre node and also for the distribution network, since low-level output was used to cover homepass not far from the fibre node and not a very big homepass. High-level output was about 47 dBmV and low-level output was about 32 dBmV. The output leg from the fibre node could be added by using a splitter or a directional coupler.

III.6.4 Amplifier (active component)

TELKOM standardized three kinds of amplifier from their function. They were trunk amplifiers, bridger amplifiers and line extender amplifiers. Each kind of amplifier also had a different leg output. Usually the trunk amplifier just had one input and one output, and the bridger amplifier had two legs output. The important thing from amplifier characteristics was noise or distortion. So TELKOM recommended that the maximum cascade amplifiers were four, both for similar amplifiers or different amplifiers in one route (Figure III.5).

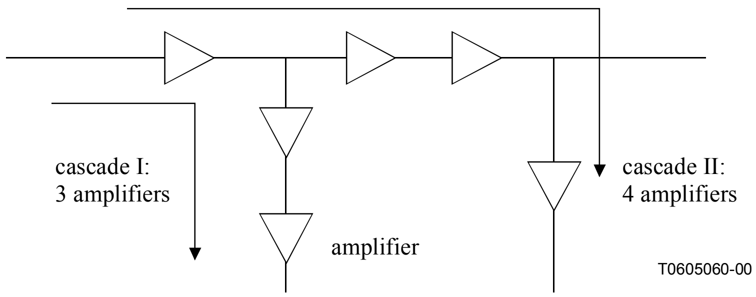


Figure III.5/L.47 – Cascade amplifier

III.6.5 Passive component

Passive components contained three components; the first was tap as splitting signal component from drop cable to the customer side, the second was splitter and the last was directional coupler to split the signal with some loss.

- There were 3 kinds of TELKOM's standard splitter; 2 ways, 3 ways and 3 ways unbalance.
- For the directional coupler there were 3 kinds, DC 8 dB, DC 12 dB and DC 16 dB.
- For tap there were also 3 kinds of tap that TELKOM standardized; 2 ways output, 4 ways and 8 ways outputs with insertion loss value from 8 dB up to 29 dB.

Consideration for output 8-way maximum for tap was the drop cable distance from tap to the customer side. It was estimated that for drop cable configuration both star and straight length of drop cable from tap to customer side should be no more than 100 metres. As we know, loss drop cable for star and straight configuration (Figure III.6) was very high, about 10 up to 12 dB in each 100 metres, compared with trunk/feeder cable that only had about 3 dB loss each 100 metres. With 8-ways tap, ideally this tap can be used, at the maximum, only for 4 homepass at right and left side. Special cases for condominium and hotels where the outlet location was not a similar model as with the residential area.

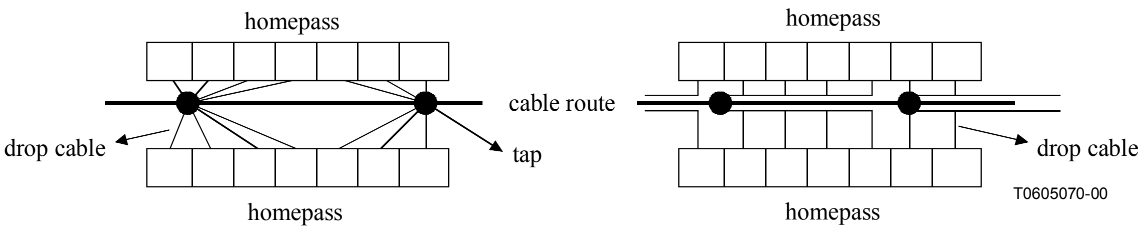


Figure III.6/L.47 – Drop cable connection to homepass

III.7 Powering system

Power was sent from fibre node in range 60 up to 90 V ac, and 10 up to 15 Ampere. To deliver power to amplifier there were two methods, distribution system or centralized. The distribution system was more complex because we should locate several power inserters for all amplifiers and also should manage the power flow with blocking power equipment in some amplifiers to avoid one amplifier getting power from some power supply. On the other hand, the centralized system was simpler, because we gave power just from one location, usually together in the fibre node cabinet.

III.7.1 Powering system in coaxial cable

a) Use Siamese cable (combined with twisted pair, see Figure III.7).

Power was delivered in twisted pair, not in coaxial cable. Usually there were some PDU (Power Distributed Unit) in tap to deliver power in the drop cable.

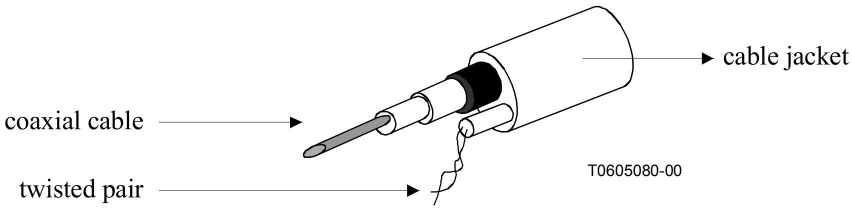


Figure III.7/L.47 – Siamese cable for powering

b) Use single cable (in coaxial itself).

This method had a corrosion effect bigger in the conductor because the conductor became hotter from the powering system.

III.8 Outside plant (OSP)

III.8.1 Pole

Because the coaxial network was still new in Indonesia, so in the application, the coaxial route could be implemented in a similar route with the copper network or a different route. For aerial application, we could pole together with telephony pole, power pole or separate pole depending on the condition and regulation in each country. The minimum distance between coaxial cable and power cable was 30 cm, and the coaxial cable had to be under the power cable. This regulation considered a higher poor cable interference factor. All amplifier positions should be at the pole, not in the middle of the pole, except passive components like splitter and tap which could be in the middle of the route.

III.8.2 Cabinet

All amplifiers and passive components on direct buried route and duct cable had been installed on cabinet or pedestal. The cabinet was made of a hot resistance isolation component supported by fibreglass components. The physical requirement of this cabinet was similar to other cabinets that were used for copper or ONU, such as good material, good corrosion resistance, water and snow protection and also had ventilation to avoid any condensation process. The cabinet also had a grounding of not more than 3 ohm. Power supply for fibre node in the cabinet should have a battery as a backup system. Splitters for leg branches in the fibre node had to be placed inside the cabinet or directly out from the fibre node amplifier. The cabinet also should have a protection pillar to protect the cabinet from crash impact.

III.9 Standardization

TELKOM had published some documents of standardization for each component, system, and also installation guidelines for HFC-C technology implementation. All standards contained rules, and requirements of technical aspects and electrical aspects for each device and system. Below are completed standards for HFC-C systems that were published by the R&D Division of PT TELKOM. Along with the process, this document could be edited and corrected according to technology development and some process of modification.

a) CIU (Customer Interface Unit) – HFC.

b) STB (Set Top Box) – HFC.

c) Cable Modem – HFC.

d) Coaxial cable – HFC.

e) Passive components – HFC.

f) Amplifier – HFC.

g) Fibre Node – HFC.

h) HEADEND – HFC.

i) Cable Telephony – HFC.

j) Cable Router – HFC.

k) System Standardization of HFC.

l) Installation Guideline for coaxial network.

III.10 Coaxial network planning tool

The R&D Division of PT TELKOM had made software to help the planning process and designing of the network, especially for the coaxial network. We called this software "TelCoNet" which stands for TELKOM Coaxial Network planning tools. This software has the ability to help design, process and network planning. Below are several capabilities of this software:

1) Location map as drawing input could be in the form of raster file (bmp, jpeg, tif) or vector format CAD (dwg).

2) To calculate downstream and upstream signal level starting from fibre node up to the demarcation point in the customer side.

3) To calculate noise and distortion that occurred such as CSO (Composite Second Order), CTB (Composite Triple Beat), XMOD (Cross Modulation) and HUM modulation.

4) To calculate power consumption both using a distributed powering system or centralized powering.

5) To calculate BoQ (Bill of Quantity) of all the cable infrastructure, amplifier and passive components.

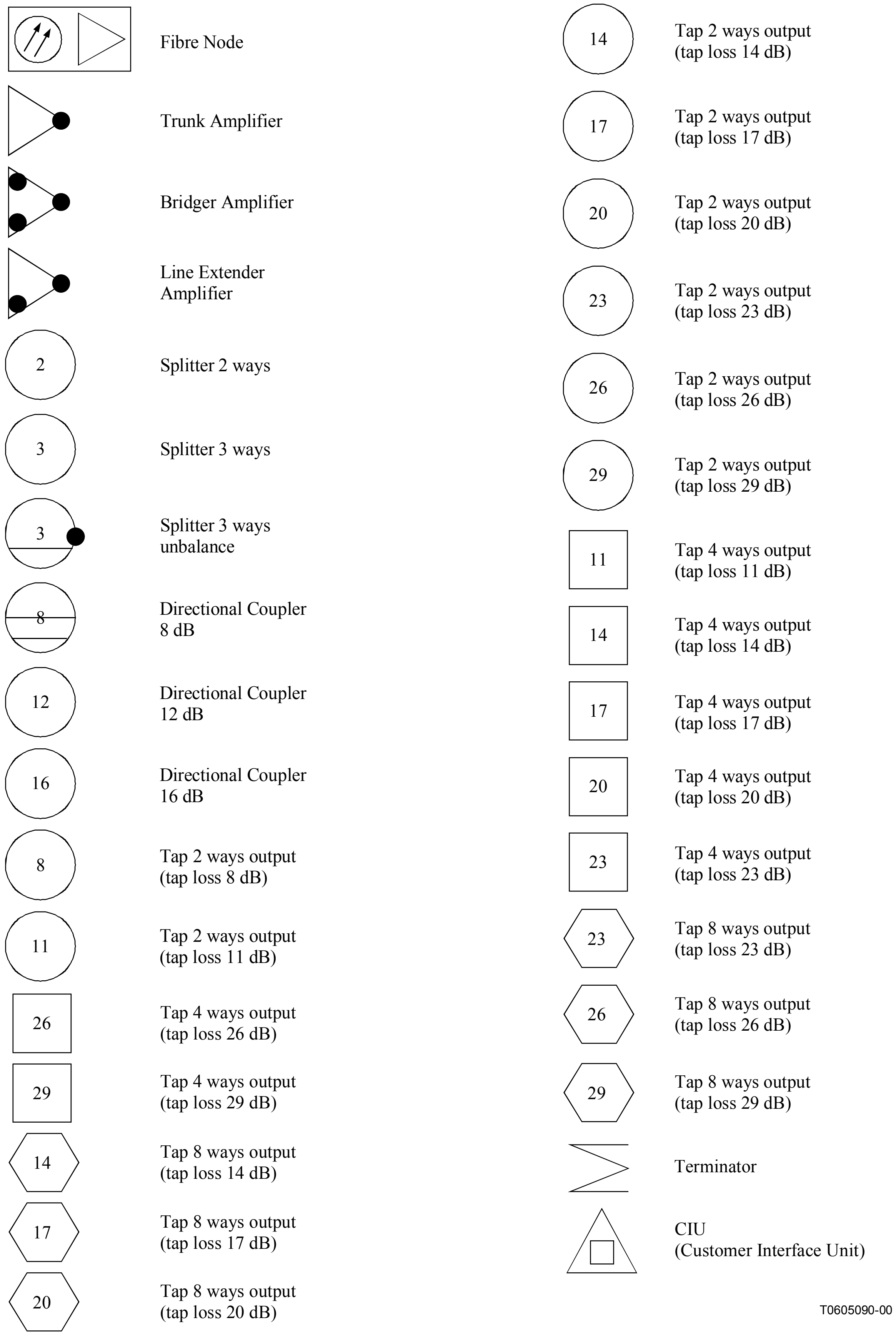
6) To calculate the total budget that should be invested to buy all the network infrastructure.

III.11 Component for coaxial HFC-C networks

Splitter: a) Splitting ratio b) Number of output ports c) Insertion loss d) HUM modulation e) Power passing	 a) Splitting ratio: 1/2; 1/3; 1/3 unbalance. b) Number of output ports 2 or 3. c) Insertion loss 2 way splitters: (maximum) 4.1 up to 5.5 dB. d) Insertion loss 3 way splitters: (maximum) 7.8 up to 9.2 dB. e) HUM modulation minimum 70 dB. f) Power passing 10 Ampere.
Directional Coupler: a) Splitting ratio b) Insertion loss c) Directivity d) HUM modulation e) Power passing	 a) Splitting ratio: 8 dB, 12 dB, and 16 dB. b) Insertion loss DC 8 dB: (maximum) 2.2 up to 4 dB. Insertion loss DC 12 dB: (maximum) 1.5 up to 3.3 dB. Insertion loss DC 16 dB: (maximum) 2.0 up to 3.3 dB. c) Directivity: under consideration. d) HUM modulation minimum 70 dB. e) Power passing 10 Ampere.
Tap: a) Number of ports b) Insertion loss c) Return loss d) Insulation among parts e) Power passing	 – Number of ports: 2, 4 and 8 way outputs. – Insertion loss 2 ways tap: (maximum) 0.7 up to 5.5 dB. Insertion loss 4 ways tap: (maximum) 0.7 up to 5.5 dB. Insertion loss 8 ways tap: (maximum) 0.8 up to 5.5 dB. – Return loss 2 ways tap: (minimum) 16 up to 20 dB. Return loss 4 ways tap: (minimum) 16 up to 20 dB. Return loss 8 ways tap: (minimum) 16 up to 20 dB. – Insulation loss: minimum 18 dB. – Power passing 6 Ampere.
Amplifier	– Trunk amplifier – Bridger amplifier – Line extender amplifier
Powering system	– Distributed system or centralized system. – 60 up to 90 V AC. – Power passing maximum 15 Ampere. – Back up battery.
Materials	– Housing should be completed by seals that resist water and humidity. – The components should be operated in an environment with temperatures from 10º C up to 50º C. – The components should be protected from EMI minimum (–100 dB). – The components should be resistant to water pressure 10 psi minimum 60 seconds inside water. – Hum modulation minimum 70 dB. – Power passing 10 Ampere.

III.12 Legend

To make similar concepts and one perception, the R&D Division published the legend for a coaxial network. This legend should be used in the planning and design process, especially in drawing network. This legend was also used in our software, TelCoNet.


Fibre Node
Trunk Amplifier
Bridger Amplifier
Line Extender Amplifier
2
Splitter 2 ways
3
Splitter 3 ways
3
Splitter 3 ways unbalance
8
Directional Coupler 8 dB
12
Directional Coupler 12 dB
16
Directional Coupler 16 dB
8
Tap 2 ways output (tap loss 8 dB)
11
Tap 2 ways output (tap loss 11 dB)
26
Tap 4 ways output (tap loss 26 dB)
29
Tap 4 ways output (tap loss 29 dB)
14
Tap 8 ways output (tap loss 14 dB)
17
Tap 8 ways output (tap loss 17 dB)
20
Tap 8 ways output (tap loss 20 dB)
14
Tap 2 ways output (tap loss 14 dB)
17
Tap 2 ways output (tap loss 17 dB)
20
Tap 2 ways output (tap loss 20 dB)
23
Tap 2 ways output (tap loss 23 dB)
26
Tap 2 ways output (tap loss 26 dB)
29
Tap 2 ways output (tap loss 29 dB)
11
Tap 4 ways output (tap loss 11 dB)
14
Tap 4 ways output (tap loss 14 dB)
17
Tap 4 ways output (tap loss 17 dB)
20
Tap 4 ways output (tap loss 20 dB)
23
Tap 4 ways output (tap loss 23 dB)
23
Tap 8 ways output (tap loss 23 dB)
26
Tap 8 ways output (tap loss 26 dB)
29
Tap 8 ways output (tap loss 29 dB)
Terminator
CIU (Customer Interface Unit)
T0605090-00

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series B	Means of expression: definitions, symbols, classification
Series C	General telecommunication statistics
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Construction, installation and protection of cables and other elements of outside plant**
Series M	TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks and open system communications
Series Y	Global information infrastructure and Internet protocol aspects
Series Z	Languages and general software aspects for telecommunication systems

Geneva, 2001