RF Video Overlay

Open Access Solutions for Video Services on PONs

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This article illustrates the enormous capacity of RF Video Overlay and its potential for introducing Open Access capabilities to new fibre networks.

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Professional career: an overview

- Degree in telecommunications engineering at the RWTH, Technical University of Aachen, Germany; graduating as Dipl.-Ing. in 1983
- 1983 to 1989: Scientific Assistant at the Institute for High Frequency Technology, RWTH, Technical University of Aachen, under Prof. Dr. Hans Juergen Schmitt
- 1989: Dissertation at Institute for High Frequency Technology, RWTH, Technical University of Aachen, under Prof. Dr. Hans Juergen Schmitt with the thesis: "Integrated Optical Isolators"
- 1989 to 1997: R&D Engineer / Head of R&D at AEG Kabel (later Kabelrheydt or Alcatel Kabel) in Moenchengladbach, Germany, with responsibility for the development of fibre optic transmission systems for broadband communication
- Since 1997: Co-founder and Managing Director of BKtel communications GmbH, BKtel components GmbH all located in Hueckelhoven Baal, Germany; BKtel Communications Beijing Ltd., P.R. China; BKtel Pacific Rim, Yokohama, Japan
- Since 2007, actively engaged in International Standardization with main focus on "Fibre-to-the home systems", IEC 60728-13 (FTTH systems), and SCTE IPS/IHC WG5, RFoG standard: IPS 910

Introduction

Open Access is an important requirement for today´s access networks allowing multiple service providers to use the same network infrastructure to the subscribers. On classical copper networks, this is achieved in such a way that the final copper cable connection ("the last mile") is leased or owned by just one of the potential service providers who then offers his services to the connected subscriber. For a change of service, the physical access to the "last mile" consequently has to be transferred to the new service provider. With the emergence of fibre optics, the opportunity arises for several service providers to share the "last mile" and offer their services, such as telephony, internet and video, side by side on the same fibre and at the same time.

RF video overlay is a technology for video transmission which provides several benefits to operators and customers currently served by PON networks and, surprisingly, adds only a small incremental cost to the required infrastructure. This article describes the technical background of RF video overlay including satellite signal transmission (e.g. DVB-S) as well as CATV (DVB-C). It illustrates the enormous capacity of this technology and its potential for introducing Open Access capabilities to new fibre networks.

Background

The low attenuation of optical signals on optical fibre allows the provision of a passive outdoor infrastructure without the need for powering and cooling, thus significantly reducing maintenance and overall operational costs (OPEX). This passive outside plant is typically called a PON (Passive Optical Network). New builds of telecommunication networks have started to use this technology, in contrast to pure copper cable technology or hybrid fiber/copper technology where optical fibres are deployed in the trunk network but using copper twisted pair cable (xDSL-technologies) or coaxial cable (HFC technology) for the "last mile".

Today, there are mainly three transmission protocols widely used on PONs: GEPON, GPON and EP2P. Each of these protocols is deemed by its supporters to be the best choice and the race is far from over. While currently GPON and GEPON are widely used in North America and Asia, EP2P is the technology of choice in most countries of Europe. The main differences between them are that GEPON and GPON are shared network approaches (point-to-multipoint or P2MP) while EP2P is a direct link approach (point-to-point). The latter approach requires a high number optical fibre connections in the central office (CO) but it has the advantage that each subscriber can permanently receive the full transmission

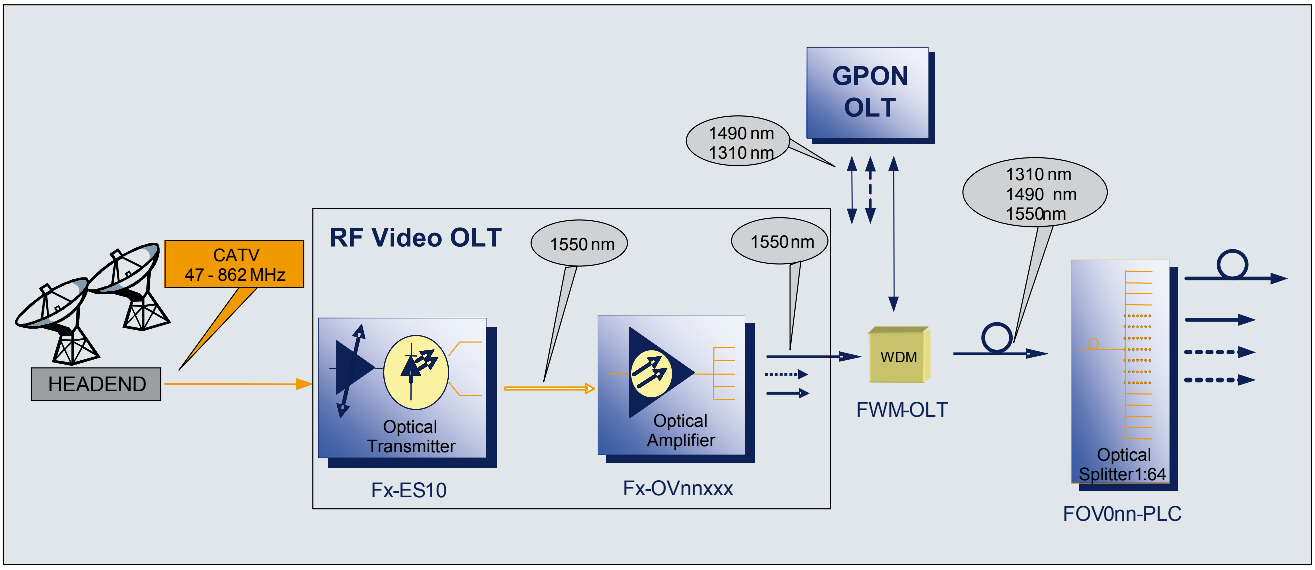

Figure 1: Block diagram of CO equipment for GPON solution with RF video overlay for CATV services

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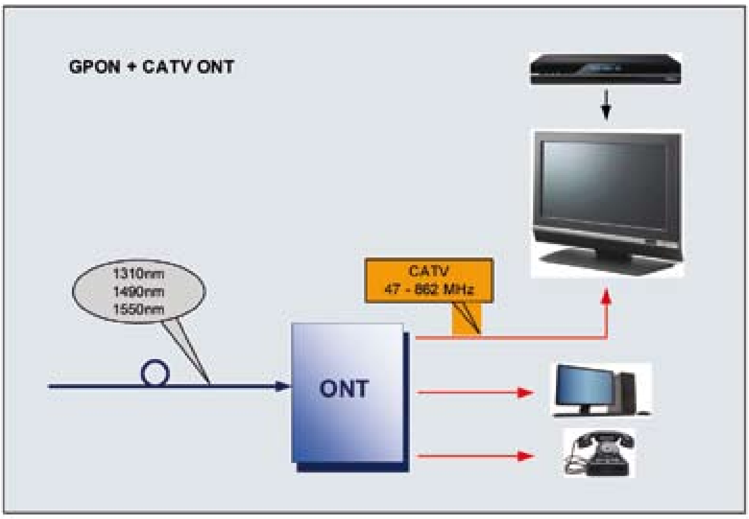

Figure 2: GPON ONT with built-in CATV RF video overlay receiver

capacity whereas by using optical splitters GPON and GEPON can significantly reduce the number of fibres necessary in the CO but the transmission capacity has to be shared among the subscribers connected to the optical splitter.

Common to all three technologies is that the transmission equipment provides Ethernet interfaces on both input and output (OLT and ONT) and consequently is ideal for the transmission of IP data for either telephony (VoIP), data (IP) or video services (IPTV). GEPON and GPON are standardized using 1490nm optical signals in the downstream direction and 1310nm optical signals in the upstream direction. EP2P systems, in many cases, simply use the same wavelengths.

It is interesting to note that the standardization bodies (ITU for GPON and IEEE for GEPON) have excluded the use of the 1550 -1560nm wavelength window on PONs for IP transmission and have even continued with this approach for the upcoming 10GPON and 10GEPON standards. The 1550-1560nm wavelength window has been reserved for a video overlay system exclusively. This video overlay system is foreseen to provide mainly broadcast type of video transmission in contrast to unicast or multicast IP video transmission which is used for video on demand or IPTV.

Figure 1 shows the block diagram of the head-end equipment of a GPON with an RF video overlay solution: the optical signals from the RF Video OLT and the GPON OLT are combined in a WDM before reaching the PON, specifically the PON splitter in the diagram. The input signal to the Video OLT in this example is a standard CATV signal.

Figure 2 shows a simple example of a GPON ONT which includes an optical receiver for the RF video overlay signal. The three different optical wavelengths on the fibre are combined or separated in the triplexer of the ONT.

In today´s HFC networks, broadcast video accounts for >90% of the total video traffic received by subscribers. The obvious reason to use a video overlay system on top of an IP transmission system is therefore to separate the broadcast traffic from the IP transmission and to utilise the available capacity of the IP transmission system only for real unicast services such as telephony, internet and video on demand. As a positive side effect, the video overlay reduces the requirements on the performance and capacity of the IP backbone network drastically.

Video services as real time services have very high requirements on the latency of the network and typically require high quality of service levels and superior IP packet buffering throughout the network to avoid disturbances in reception such as freezing pictures. Unfortunately, video services will also tend to become even more demanding in the future with 3D-TV already knocking at the door and next-generation VHDTV (3840x2160 pixels) and UHDTV (7680x4320), already defined as future standards, requiring even higher transmission rates. It is therefore a serious option to provide broadcast video services, via a video overlay system, on a PON infrastructure. Video overlay does not necessarily mean just a CATV signal broadcast; it enables the option of an Open Access video transmission platform which is explained in the next section.

Open Access RF video overlay

The only requirement for the optical interfaces of an RF video overlay system, used in conjunction with a GPON, GEPON or EP2P system is that they have to transmit optical signals in the 1550-1560nm window and should not interfere with the IP signals. The prevention of linear interference (crosstalk to or from the IP signals) can, in general, be achieved easily by

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using adequate quality optical diplexers in the OLT and the ONT. The more challenging problem evolves from non-linear crosstalk due to the very high optical power levels on the PON. The good news is that the resulting impairments are only on the RF video overlay signals and not on the IP signals. Non-linear crosstalk caused by Raman Scattering might be visible with analogue transmitted video signals (such as PAL- or NTSC AM-modulation); digital modulated signals (QAM) are, in general, sufficiently robust not to suffer any impairment. In all cases, proper design of the optical power budget on the PON will avoid these problems from the start.

The kind of signals to be transmitted on the RF video overlay system can vary widely. The classical approach is to transmit CATV signals in the frequency range from about 45 … 1000MHz. There are many GPON, GEPON and EP2P solutions which offer a built-in CATV RF video overlay system as an option and therefore support native DVB-C transmission on the PONs.

Some solutions offer an extended frequency range up to about 2200MHz. In this case, both a CATV and a satellite DTH service (DVB-S) can be offered; even as an Open Access video system for two different video service providers.

Alternatively, the focus of an RF video overlay system can be more on satellite DTH (DVB-S) and less on CATV transmission. In this case, RF overlay solutions are available which carry more than one satellite L-band (950 … 2200MHz) by frequency stacking two L-bands to 950 … 3750MHz. For Ku-Band satellites, as commonly used in Europe, (e.g. ASTRA, EUTELSAT) two low/high bands can be stacked i nto the 950 … 5750MHz frequency range. These multiple L-band solutions can be extended with a low performance TV transmission channel (e.g. 200 … 800MHz) suitable for 'free to air' channels in DVB-T standard. The output signals of RF video overlay solutions are inherently compatible with standard TV sets (AM TV) or today´s "HD ready" TV sets in case of DVB-T, DVB-C or DVB-S transmission, provided that the TV set is equipped with an appropriate tuner or uses an external set-top box.

Table 1 shows the DVB data rate capacity of the different RF video overlay options. With the current modulation / coding schemes, the data rate capacity of an RF video overlay system offers between 3 and 10Gbit/s of video broadcast transmission capacity. This capacity can be significantly increased by using DWDM within the available 1550nm wavelength window. Solutions with up to 8 DWDM channels have been proposed, increasing the total video data rate capacity by a factor of 8.

RF video overlay solution	# of AM TV channels (PAL, NTSC)	# of QAM channels (DVB-C)	# of 8-PSK channels (DVB-S)	DVB total data rate
CATV	35	59	-	3.04 Gbit/s
DVB-C	-	94	-	4.85 Gbit/s
CATV + 1 x DVB-S	35	59	25	5.54 Gbit/s
DVB-C + 1 x DVB-S	-	94	25	7.35 Gbit/s
1 x DVB-S	-	-	25	2.50 Gbit/s
2 x DVB-S	-	-	50	5.00 Gbit/s
4 x DVB-S	-	-	100	10.00 Gbit/s

Notes:
CATV: Typical numbers as frequently applied in today´s networks
AM TV: comes in general also with ~36 FM radio channels
QAM: 256-QAM with 6.8Mbit/s symbol rate and 188/204 RS FEC suggested
DVB-S: L-band 950 …. 2200MHz with 8-PSK and 36Mbit/s symbol rate, 9/10 BCH-LDPC and 188/204 RS FEC suggested

Table 1: DVB data rate capacity of RF video overlay transmission technologies

RF overlay solution	Number of channels @ OMI				SNR @ Pin	Pin
	AM-TV	FM radio	256-QAM	8-PSK TV	dB	dBm
CATV	35 @ 4%	36 @ -4 dB	59 @ -6 dB	-	45.7 @ AM-TV	-10
DVB-C	-	-	94 @ 2.2%	-	33.5 @ DVB-C	-13
CATV + DVB-S	35 @ 3.8%	36 @ -4 dB	59 @ -6 dB	25 @ -16 dB	45.8 @ AM-TV	-8
DVB-C + DVB-S	-	-	94 @ 2.2%	25 @ -10 dB	33.5 @ DVB-C	-10.5
1 x DVB-S	-	-	-	25 @ 6.7%	11 dB @ DVB-S	-23
2 x DVB-S	-	-	-	50 @ 4%	11 dB @ DVB-S	-19
4 x DVB-S	-	-	-	100 @ 2.4%	11 dB @ DVB-S	-16.5

Assumptions:
CNR contributions of TX + EDFA + RX considered
Noise bandwidths = 5 / 6.8 / 36MHz @ AM / 256-QAM / 8-PSK
SNR@CATV = CNR@CATV + 1.5dB
Optical receiver input noise current = 4.5 / 8 / 16 pA/√Hz @ 862 / 2200 / 5450MHz
All non-linear effects neglected

Abbreviations:
OMI : optical modulation index
Pin : optical input power
SNR : signal-to-noise ratio
ONU : optical network unit
OLT : optical line termination
V-OLT : video OLT

Table 2: Minimum required optical input power for video overlay ONU

The enormous data rates provided by an RF video overlay system enable the allocation of capacity to several video service providers, introducing Open Access for video services on the PON. Naturally, if a subscriber is connected via an optical fibre, there is no further need for an additional coaxial cable to receive CATV signals or a satellite dish to receive satellite signals. Therefore, the traditional video service operators have a strong motivation to offer their services on the PON either via DVB-C for the CATV network operators or via DVB-S for satellite operators.

To operate an RF video overlay system succesfully, the available optical budget between the output of the V-OLT and the V-ONU is crucial. Since the launch power into the PON is limited, for several reasons, to about 19dBm for the video overlay signal the minimum required RF video ONU input power to achieve an acceptable service quality is of great concern. Table 2 gives an overview showing the minimum required optical input level of a video ONU depending upon the different RF video overlay solutions. The different nature of AM-TV, DVB-C and DVB-S signal transmission leads to different requirements for the SNR (signal-to-noise ratio) at the output of the video ONU. For the widely used CATV RF video overlay, about -10dBm of optical input power, is sufficient to achieve satisfactory video picture quality. With a maximum launch power of +19dBm from the V-OLT, this provides a maximum 29dB optical budget, exceeding the requirements of the GPON or GEPON standards.

If the AM TV as well as FM radio channels signals are replaced with DVB-C channels, a 3dB improvement can be achieved, which can be used to halve the V-OLT related cost per subscriber.

The transmission of pure DVB-S signals increases the optical budget dramatically due to the very robust nature of DVB-S transmission which requires a SNR of only about 11dB. Consequently, optical budgets between about 42dB (single L-band DVB-S transmission) and 35.5dB (quad L-band DVB-S) transmissions can be achieved. PONs with a

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pure DVB-S video overlay solution therefore have the highest optical budgets. Thousands of subscribers can be connected to just one +19dBm port of a V-OLT.

As a side note, today´s high power optical amplifiers as used in V-OLTs are available with up to 16 or even 32 ports. Therefore, the cost contribution of the V-OLTs in most cases can be negligible due to the large number of subscribers sharing just one V-OLT.

Summary

RF video overlay technologies are available supporting the transmission of video signals used in fibre optic networks. A single wavelength RF video overlay solution typically transmits at a video data rate of between 3 and 10Gbit/s; for a multi-wavelength DWDM solution, this capacity can be significantly extended.

On a PON infrastructure, RF video overlay is therefore a very attractive option to enable Open Access to several video service providers. The broadcast video data rate capacity can be used to offload broadcast or multicast video transmission from the IP PON transmission system (e.g. GPON, GEPON or EP2P) significantly reducing the requirements on the IP backbone performance and capacity and therefore lowering the cost of the complete network.

Today´s CATV and satellite operators have a strong motivation to participate in this technology solution since future fibre-connected homes will no longer need coaxial cable or a satellite dish to receive video signals.

2011 Technology Innovation awards

Nominations are now being sought for the 2011 SCTE Technological Innovation awards which will be presented at the SCTE Gala Dinner on Saturday 2 April 2011. Following the massive sell-out success of our previous dinners, this is sure to be another success especially as the 2011 event is being held at Hatfield House in Hatfield (Herts). Awards will be given for three separate categories:

- ‘Best broadband network transmission solution’
- ‘Best CPE solution’
- ‘Best digital processing solution’

Nomination forms are to be forwarded to the SCTE office no later than the end of January 2011. See www.theSCTE.eu.