PROJECT FINAL REPORT

Grant Agreement number: 230881

Project acronym: OPTOSAT

Project title: DBS LNB-STB Optical Fibre Transmission Link

Funding Scheme: Research for the Benefit of SME's

Period covered: from 1st January 2010 to 31st December 2011

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement .
[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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1. Executive summary

Background and Objectives

Satellite TV signals are currently carried from the dish to each viewing location in a residence over coaxial cables. With the advent of satellite receivers with multiple tuners this has become problematic since one cable is required per tuner, resulting in many cables needing to be installed, which is costly, time consuming and disruptive. Optical fibres are an attractive alternative to coax owing to their small size, light weight, very low loss, and price. Systems based on these are already being offered by one of the project's partners, however whilst suitable for use in larger systems in MDUs, they are too costly for use in small scale installations such as single family homes (SFHs). The Optosat project was formed to investigate low cost approaches to satellite TV distribution based on optical fibres, which would meet the requirements for these small scale installations.

Outputs/Achievements

Within the Optosat project a prototype demonstrator system, based on low cost optoelectronic components, has been designed, built, and tested. Various options for the system architecture were studied, a key requirement being that the overall system cost be minimised in order to make it suitable for use in the SFH scenario. The use of lasers with different wavelengths (colours) to carry the four satellite bands over a single optical fibre was initially considered, however the design study concluded that, whilst technically feasible, the costs involved were prohibitive owing to the high cost and complexity of the required optical components. An alternative architecture was decided upon, which uses four separate fibres within a single cable assembly, each carrying one of the four bands of satellite TV. The benefit of using separate fibres is that identical lasers sources and optical detectors may be used for each, thus avoiding the cost associated with combining the bands onto a single fibre and separating them in the receiver. Furthermore, the project has concluded that cheap digital VCSEL lasers and detectors, together with multimode fibre, which are already mass produced for the datacoms market, are suitable for an analogue application such as this. This is a key result as it enables a significant reduction in the overall system cost to be achieved. Additional functionality was added to the system by overlaying an optical Ethernet data network onto the same fibres using WDM techniques. This was achieved using commercially available equipment which operated at a different wavelength from the TV signals. Prototype transmitter and receiver modules were designed, assembled and tested, and additionally the receiver PCB assemblies were integrated into a commercial satellite receiver thus producing a STB with an optical only input. These units have been used to undertake two separate field trials, one in a domestic dwelling in Spain, and

the other at another partner's offices which was done so as to emulate a domestic installation. The results from both trials were consistent, and demonstrated the system's capability to carry the full set of channels from a single dish to multiple locations within the home as well as providing data connectivity between those locations.
Having demonstrated the capabilities of this approach, interest is being sought from major broadcasters, in order to take the next steps towards developing the concept into a commercially available product.

Consortium Members

Global Invacom Ltd, Red Embedded Design Ltd, Electronica Seyma SL, Cube Optics AG, UK-ISRI, University of Kent, Centre National de la Recherche Scientifique, Modulight Incorporated

Further Information

For further information on the Optosat project, please visit the projects main web site at: www.optosat.com

2. Summary description of project context and objectives

Project Context

Over the past two decades there has been an explosion in the adoption of satellite TV with BSkyB now having an installed customer base of over 10 million in the UK, and although this market will begin to saturate, upgrades and replacement installations are still expected to run at ~ 1 million per annum for the foreseeable future. The total European market is several times this size with ~300 million installed STBs, and where it is common for customers to install their own systems. Where a system involves more than two STBs these systems become complex, typically requiring RF switches which are costly and require a degree of expertise to design a workable solution. Given this background, there is a clear demand for a new low cost, simple to install, system and it is believed that a solution based on optical fibre technology is the answer.

A satellite TV installation typically comprises a satellite dish and LNB to receive the signals, a coaxial cable network to transport the signals to the required viewing locations, and satellite receivers (STB) to decode the signals, and TVs to view the programme content. The bandwidth of the signals received from the satellite at the dish is ~4 GHz, which is beyond the capability of coaxial cables to carry over the distances required in SFHs and MDUs. To overcome this problem, within the LNB the content is split into four separate bands approximately 1 GHz wide and located in the frequency band 1 to 2 GHz. This frequency range is within the capabilities of reasonably price coaxial cables, but does mean that each coaxial cable can only carry one band at a time, which is approximately one quarter of the content being transmitted. In a SFH one cable is run to each viewing location, and signalling from the STB enables the LNB to select the appropriate band and transmit it over the coax to the STB. When a channel on another band is required, the STB signals the requirement to the LNB which then routes the appropriate band over the coaxial cable.

Modern satellite receivers now include multiple tuners enabling one or more program to be recorded whist yet another is viewed. In order to support these extra tuners, extra coaxial cables are required, one per tuner, which can require as many as eight or even more cables, the installation of which is costly, time consuming, unsightly and disruptive.

In MDUs the situation is slightly different, but the issue with the profusion of cables is still the same. Whereas in the SFH where up to typically four viewing locations may need to be supported, in an MDU several tens of apartments will need to have services provided from a single dish and LNB, and there may be several view points in each of these. Clearly many tens of coaxial cables cannot run back to a single LNB, so instead a backbone comprising four coaxial cables, one for each satellite frequency band, is installed. Nodes on this backbone, which comprise a splitter and switch (multi-switch) provide connectivity between the apartments and the backbone. The purpose of this multi-switch is to tap off the signals from each band, and to route them as required into the apartments located in the node's vicinity. The switching capability in the node enables the signals from any one of the four cables (bands) to be routed to a STB in the apartment in exactly the same way as with the LNB in the SFM scenario. Once again, one cable from the node is required for each tuner, meaning that there is again a profusion of cables required to support the multiple tuners in the STBs, and the multiple viewing locations is each apartment.

The issue of multiple cables arises because of the limited bandwidth afforded by the coaxial cables. One of the key features of optical fibres is that they have very high bandwidths and in many instances this is limited by the components (lasers, detectors, etc) to which they are connected rather than the fibre itself. In addition to this, optical distribution of these satellite signals has the advantages of being easier to install (smaller cables), are electrically isolating thereby eliminating electrical shock hazard and the associated requirement for earth bonding, and are immune to EM interference. Global Invacom have developed a range of fibre based products which allow the distribution of satellite TV signals over a passive optical network, where the signals originate at a single location and are split, typically 32 ways, and distributed throughout a building [1]. To achieve this the four satellite bands are first combined into one composite signal by frequency stacking them in the frequency range 1 to 5.5 GHz. This composite signal then modulates a laser to generate the optical signal which is broadcast over the passive optical network. At each receiving point an optical receiver converts the signal back to RF, and then de-stacks the signal, converting each of the four bands back to their original frequencies, thus providing a STB with the RF signals as if it were connected directly to an LNB.

This system is cost effective in the MDU environment, but owing to the way in which the signals are stacked at the headend (in the bespoke LNB), and then de-stacked in the receiver in the dwelling, the costs are prohibitive for use in a SFH. The component costs associated with the frequency stacking/de-stacking, which requires high frequencies mixers, PLLs, etc., make it difficult to reduce the product costs below a certain point.

Given the background described in the previous section, there is a clear requirement for a low cost system for the distribution of satellite TV signals from the receiving dish to multiple viewing locations in the home, capable of supporting multiple tuners in a STB, without requiring a profusion of coaxial cables. The solution needs to be backwards compatible with the installed base of STBs, and it is desirable that it is simple to install, ideally by the homeowner themselves, have low energy consumption, and be immune to the problems associated with electromagnetic interference. In addition to these considerations account needs to be taken of the moves being made by the major broadcasters to facilitate the material recorded and stored on a STB in one location being played back and viewed elsewhere in the home. This requirement means that it would be beneficial if the system designed provided Ethernet connectivity between the different viewing locations/equipment within the home.

Optical fibre based solutions solve many of the problems highlighted, however the main stumbling block has been reducing the cost to the point where the solution is economic for SFHs as well as MDUs. The objective of the Optosat project was to investigate alternative approaches to this, studying different architectures, technologies, and components, and to design and construct a demonstration system.

Objectives

As described in the previous section, the Optosat project was set up to investigate the options for reducing the costs of a fibre based system for the distribution of satellite TV signals within the SFH environment.

The fundamental question that required answering was are there alternative approaches to transmitting the four satellite frequency bands over a cable other than the frequency stacking approach already developed. The project was set up to look into the possibility that this could be accomplished using WDM technology [2]. In this instance optical sources (lasers) with different wavelengths (colours) are used to carry the different bands, and because the lasers are at different wavelengths they can be combined onto the same fibre, and then separated at the receiver, using optical filters. Another approach to be investigated was the use of separate fibres for the four bands, which eliminates the requirement for the WDM filters, thereby reducing costs. Whilst at first sight this may appear to conflict with the requirement that the number of cables be minimise, because of the small size of an optical fibre, many fibres may be included in a single cable assembly, and it is straightforward to manufacture a cable carrying four optical fibres and still keep the cable size significantly less than that of a single coaxial cable.

Aside from the question of the system's architecture the project was also set up to investigate the availability of low cost optoelectronic components suited to the transmission of the satellite TV signals. In particular work packages were included investigating the performance of low cost lasers and detectors, and their suitability for use in this application.

The overall target for the project was, having selected the system architecture and identified the optical components to support the design, to produce prototype transmitter and receiver modules and to use these to assemble a demonstration system which would be used to undertake field trials.

3. Description of the main Scientific and Technological results

System Architecture

As explained in the previous sections, the technical objective of the project was to find a cost effective way of transporting the four 1 GHz bands of satellite TV broadcasts from a head end unit mounted close to the satellite dish, over a fibre network, to multiple viewing locations in the home. Initially the project investigated the use of WDM techniques to combine the outputs from multiple lasers, each carrying one of the satellite four bands, onto a single optical fibre to transmit them to the viewing locations. Investigations carried out early in the project concluded that suitable low cost lasers for this approach are not currently available and are not expected to be for the foreseeable future. Whilst lasers such as CWDM DFBs emitting in the 1310 and 1550nm wavelength bands, and their associated MUX/DEMUX components, could achieve the desired functionality, the cost of such sources alone would exceed $400 for a single transmitter module, which is more than an order magnitude higher than the target. Optical sources are available at other wavelengths, for example 850, 665 and potentially 520 nm, however not all of these have the required modulation bandwidth or can be used on the same type of fibre. In addition, multiplexing these particular wavelengths onto a common fibre is not done elsewhere, and so suitable multiplexing components are not commercially available and their development and was considered beyond the scope of this project. Given these considerations the project concluded that the use of WDM was not a viable approach and an alternative methodology was sought.

Space division multiplexing (SDM), rather than wavelength division (WDM), is an alternative means of transmitting parallel data streams albeit over a physically separate path. Figure 1 below shows the system architecture when using this approach. A quatro LNB, which has four outputs each dedicated to one of the four satellite bands, is connected an Optical Transmitter Module located close to the LNB. Within this transmitter module the signals from each of the LNB outputs are amplified and used to directly modulate a laser, the output from which is then split and routed to the four viewing locations. In this scheme four fibres, each dedicated to one of the satellite bands, are routed to the view locations, however it is worth noting that these four fibres would be housed within a single cable assembly, which is far more compact than a single coaxial cable. The scheme therefore satisfies the criteria that it eases installation and minimises the number of cables used.

At the viewing location a receiver module, containing a photodetector and amplifier for each of the fibres, converts the signals back to the electrical domain, and feeds them to a STB in a form identical to as if it were connected directly to an LNB. This optical receiving circuitry will eventually be built into the satellite receiver itself, however a separate module will be required initially in order to support the existing installed base of legacy STBs.

The principle benefit with this architecture is that there are fewer constraints when selecting the optical source, enabling it to be on the basis of cost and performance only, without the additional constraint imposed by the wavelength multiplexing requirement. This opened up the possibility of using the optoelectronic components used in datacoms applications, which are mass manufactured and are available at relatively low cost. Whilst this appeared an attractive approach to take, there was no evidence in the literature to say whether the analogue performance of these components at the frequencies of interest is suitable for the transmission of the DBS signal format used for satellite TV. A major part of the activity was therefore to investigate the performance of these components for this specific application.

Additional functionality may be added to this architecture by overlaying an Ethernet link as is shown in the Figure 1. The project envisaged achieving this using the 1000BASE-LX standard which employs 1310 nm wavelength lasers, the modules for which are commercially available. The overlay can either be achieved by adding an extra two fibres, one each for the upstream and downstream traffic, or by using WDM techniques to add the signals to two of the fibres already carrying the satellite TV signals. In addition to providing internet connectivity to each viewing location, this functionality also facilitates communication between the different set top boxes connected, and enables content recorded or being viewed on one unit to also be viewed on another elsewhere in the home. Within the project the WDM approach was taken to demonstrate this capability.

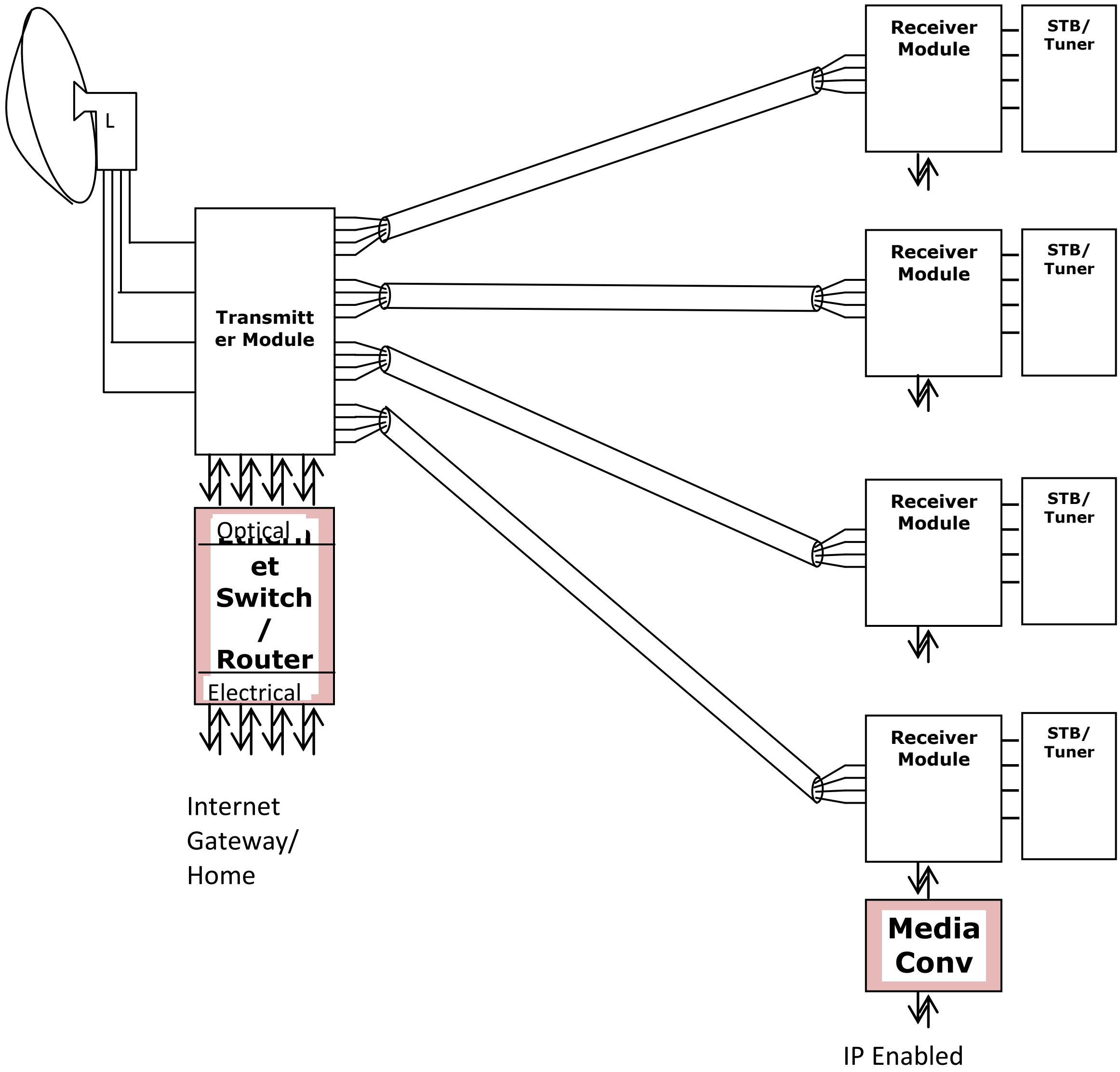


Figure 1 System Architecture using Space Division Multiplexing

Optical Components and System Link Design

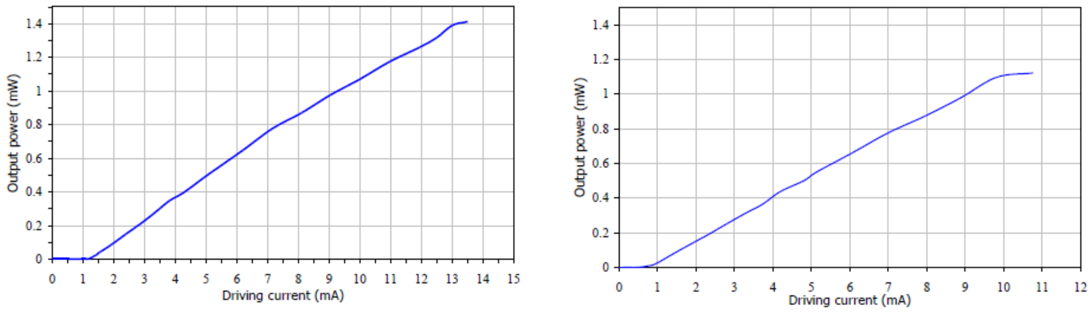
The availability and performance of lasers and detectors capable of carrying the DVB satellite TV signals with frequencies extending up to 2.15 GHz was investigated [3]. All types of semiconductor lasers were considered, Fabry Perot (FP), DFB, and VCSELs, emitting at the common wavelengths of 850, 1310, and 1550 nm. Whilst any of these classes of lasers can be procured with the requisite bandwidth capability, it is the cost requirement which proved to be that which determined the optimum choice. Multimode VCSEL lasers, emitting at 850 nm are cheap to fabricate and package, and transmitter optical subassemblies (TOSAs) which use these VCSELs are manufactured in large numbers for the datacoms industry, and are as a consequence the most price competitive. Whilst there was little in the literature to say whether they would have the linearity and noise characteristics required for this analogue transmission application, the decision was taken to pursue these as the primary design path, and emphasis in the project was placed on establishing whether their analogue modulation characteristics were satisfactory. The situation with the optical detector was similar to that of the lasers. GaAs PIN photodiodes are used in high volumes in the datacoms market, are cheap and are readily available as receiver optical subassemblies (ROSAs) usually with an integrated front end transimpedance amplifier (TIA) [4]. Again the analogue performance is not publicised since their primary application is in the datacoms arena which employs digital modulation, and this was also investigated at an early stage.

<u>Laser Evaluation</u>

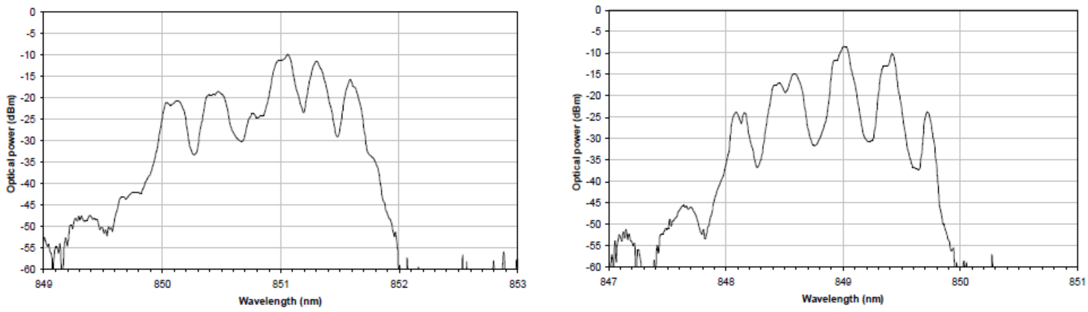
Multimode VCSELs are readily available, and those which appeared best suited to the Optosat project were those aimed at 2.5 and 4.25 Gb/s digital modulation rates in datacoms applications. Both of these variants were characterised, and the figures below illustrate the performance characteristics measured for these parts [5].

Fig

ure 2 shows the power versus current and spectral characteristics measured for the two device variants. Both are seen to be capable of providing output powers of up to 1 mW and exhibit the multimode emission spectra expected from this class of device.



L(I) curve for TOSA2.5G (left) and TOSA 4.25G (right).



Output optical spectrum for TOSA2.5G (left) and TOSA 4.25G (right) at 50% bias

Of particular interest was the analogue modulation bandwidth and linearity characteristics of these devices. Figure 3 below shows the frequency responses measured. The results indicate that there is little difference in the modulation bandwidth of the two parts, and that there is a 2 dB roll off in gain across the frequency band of interest which was considered to be manageable.

The measured gain compression characteristics for the two parts are shown in Figure 4. As would be expected, the bias conditions influence the 1 dB input compression point, with better linearity being seen at the higher drive levels. Again little difference was seen between the two variants of this device.

Based on these results the 2.5 Gb/s variant was selected for the prototype transmitter build as its performance was adequate and it was the cheapest option.

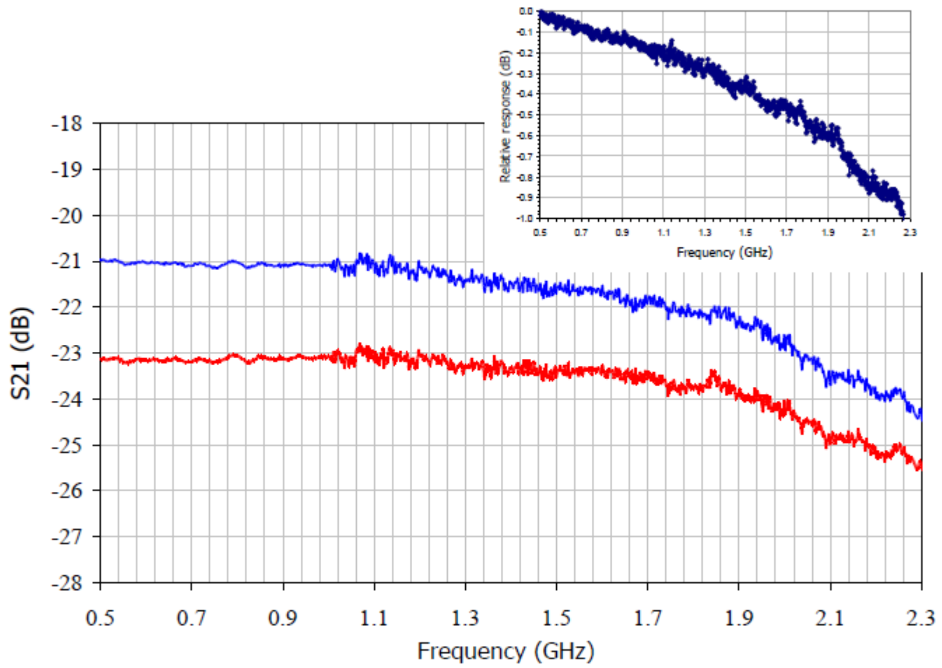
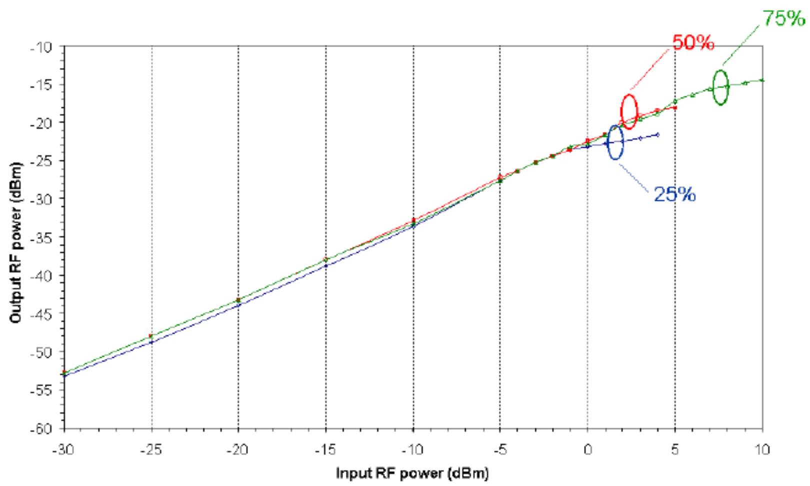


Figure 3 Frequency responses of 2.5G (blue) and 4.25G (red) TOSAs



Bias conditions	Frequency (MHz) 950	1500	2150
25%	0	+ 0.5	+ 2
50%	+ 4	+ 5	+ 8
75%	+ 8	+ 8.5	+ 10

Bias conditions	Frequency (MHz) 950	1500	2150
25%	0	0	+ 1
50%	+ 4	+ 4.5	+ 6
75%	+ 7	+ 7	+ 8

Input 1dB compression point for TOSA2.5G (left) and TOSA4.25G (right)

Figure 4 TOSA 1dB compression point measurements
The plot shows typical measurements for a 2.5G TOSA at 950MHz under different modulation conditions. The table compares the data for the 2.5G and 4.25G devices.

Detector Evaluation

A similar exercise was undertaken for the detector, which are procured as ROSAs (Receiver Optical Subassemblies). Although these components may be purchased with or without integrated TIA front end amplifiers, since those which include the TIA are manufactured in much higher volumes they are available at significantly lower cost, and hence priority was given to determining whether they were fit for this application.

Versions designed for 2.5 and 4.25 Gb/s datacoms systems were again available and their performance was compared in a similar manner as for the VCSELs [6]. Figure 5 below shows the measured frequency responses for the two variants indicating that that there is only a small advantage in using the more expensive 4.25G ROSA, and that the frequency roll off across the band with either part is manageable. The lower cost 2.5G part was therefore selected.

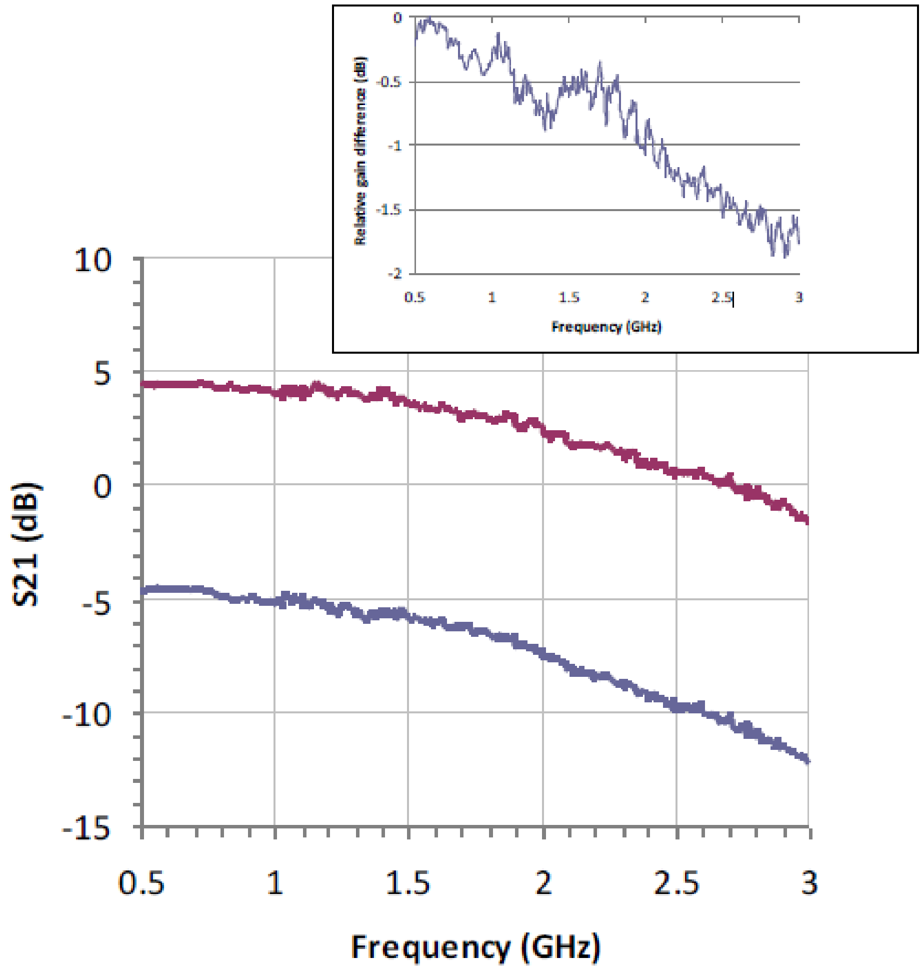


Figure 5 Frequency response 2.5G (bottom) 4.25 (tp) ROSAs

Fibre

The cheap TOSA sources and ROSA detectors selected are designed for use with multimode fibre, and whilst this fibre's bandwidth and loss characteristics at 850 nm, shown in table 1, is inferior to that of a single mode fibre when used with 1310nm sources, the manufacturers data (table 1) suggested that it would be suitable for use over the ~50 m span lengths required for an installation in a SFH. There was a question as to whether modal noise effects, which degrade performance in some multimode systems, would degrade the signals, however no evidence for this was seen in any of the component or system testing undertaken.

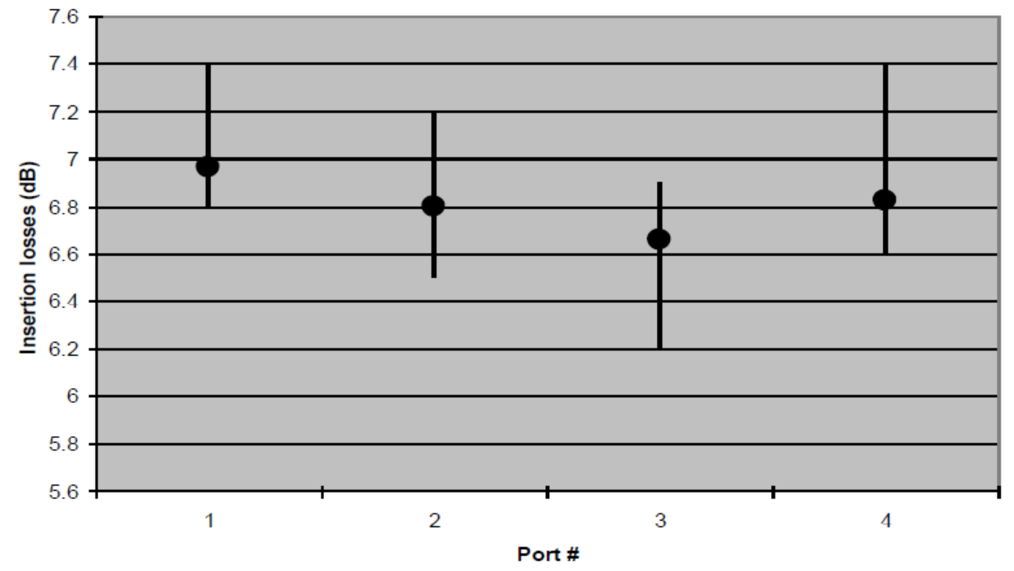
Table 1 Fibre specifications from two manufacturers

	MMF 1	MMF 2
Type	Corning ClearCurve OM2	Draka MaxCap-BB OM2
Attenuation	<2.3 dB/km	<2.1 dB/km
Bandwidth	850 MHz.km	>500 MHz.km
Bend loss	<0.2 dB at 7.5 mm, 2 turns	<0.2 dB at 7.5 mm, 2 turns
Ref:	[10]	[11]

Passive Components

Passive optical components, optical splitters and wavelength multiplexers, are also required to realise the Optosat system architecture, including the Ethernet overlay. Specifications for these parts were developed as part of the project, and samples manufactured to this specification by one of the partners, Cube Optics .

Two design variants for the transmitter module were considered in the project which are described later in this report, and are shown in Figure 12. In one of these variants the output from each laser is split four ways to provide the signals to be broadcast to each of the four viewing locations the system has been designed to support. In order to minimise the power requirements from the lasers, and to maximise the system margin, it is desirable that these splitters have low loss and uniform outputs from each of the four ports. Figure 6 shows the measured characteristics for the splitters manufactured. The results show a mean insertion loss of only 6.8 dB ± 0.6 dB, and a channel imbalance of ± 0.2 dB, which is more than adequate for this application.



Mean (dots), minimum and maximum values of splitter insertion losses.

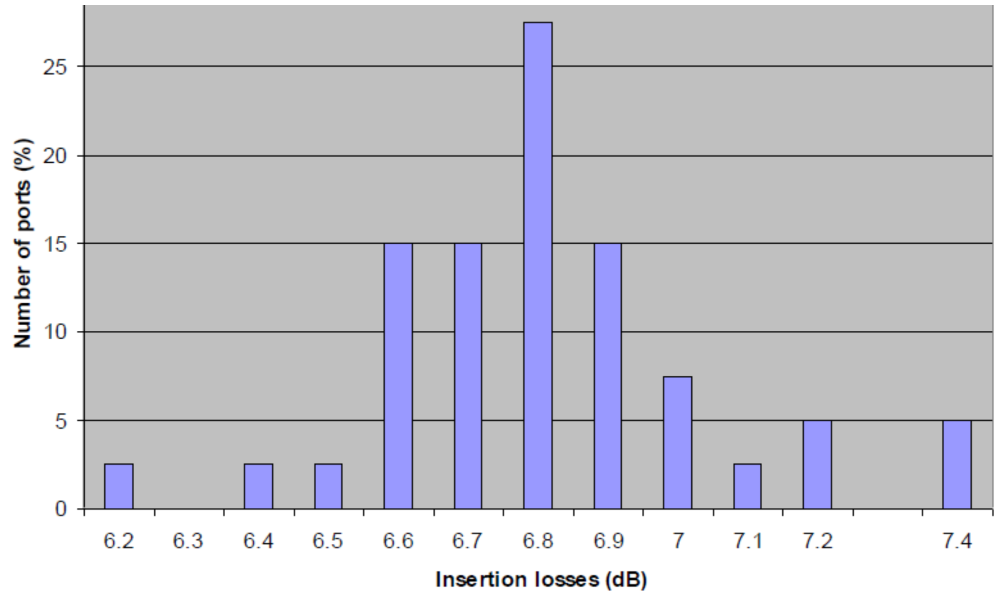
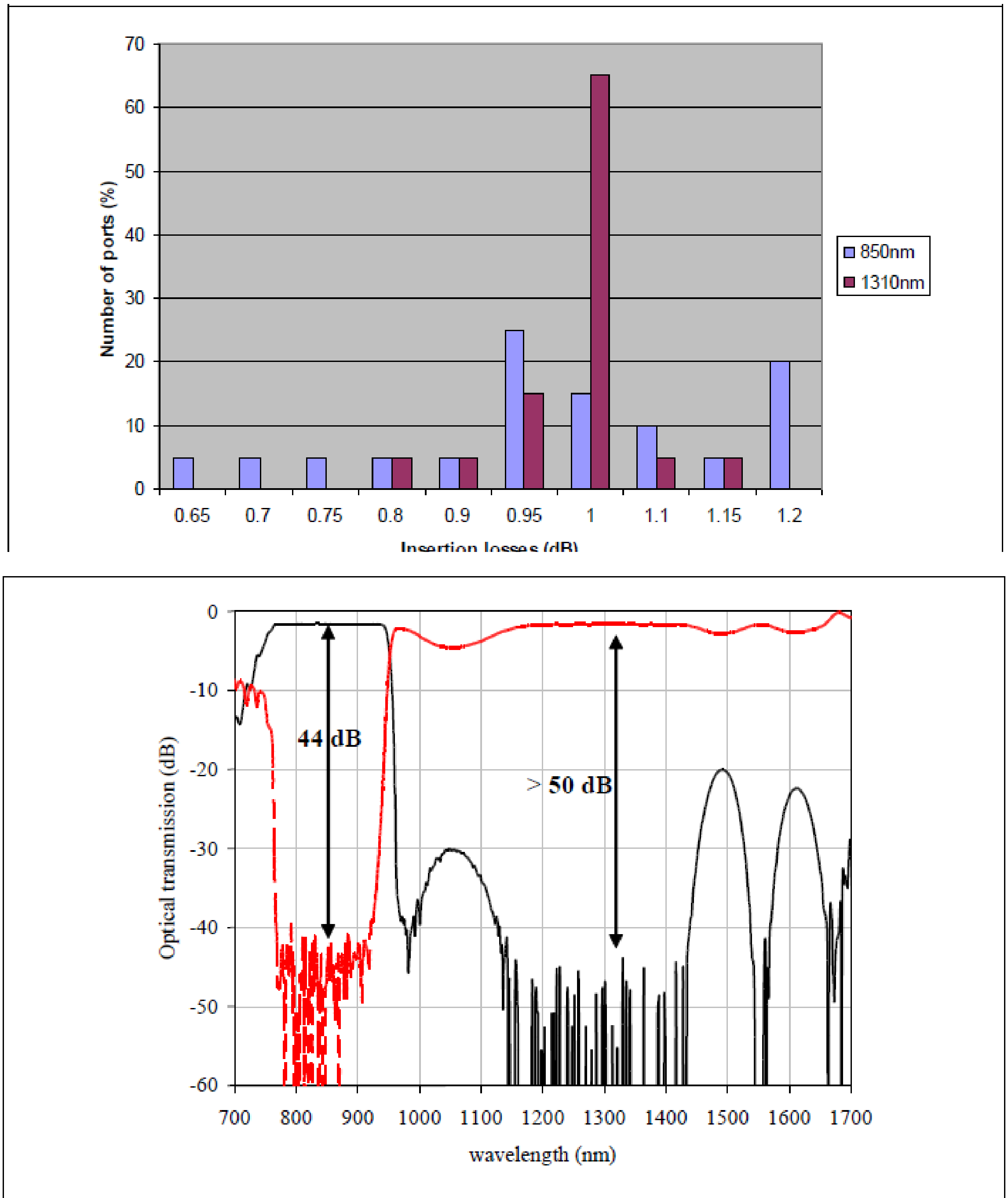


Figure 6 Loss measurement results for 10 optical splitters

WDM multiplexers capable of combining/separating the satellite TV signals transmitted at a wavelength of 850 nm wavelength with the Ethernet traffic carried at 1310 nm were also built. Figure 7 below shows the insertion loss and isolation characteristics for these devices, indicating that the average insertion loss was 1 dB, and that that the maximum value observed was 1.2 dB. The isolation values show that the worst case optical isolation is 44 dB, which in the electrical domain equates to double this, i.e. 88 dB, which is more than adequate.



Output spectrum of 850 nm port (black curve) and 1310 nm port (red curve).

Figure 7 Loss measurement results for 10 WDMs and an isolation characteristic for one unit

System Link Design

Prior to the construction of the prototype modules and system demonstrator a detailed analysis of the system link budget was undertaken [8]. The analysis was undertaken using a combination of datasheet and measured parameter values for the selected components. The system model constructed was capable of predicting the signal level and carrier to noise ratio (CNR) at the output of the system where the satellite receiver (STB) would be connected. The assumptions used in the analysis regarding the system parameters and optical component characteristics, etc, are shown in Table 2, and are considered to be a realistic worst case scenario.

Table 2 Parameters used for system modelling

System Parameters	**Value**
Channel Bandwidth	33 MHz
Number of Channels	30
Input power per channel into LNB amp	-80 dBm
LNB amp noise figure	1 dB
STB receiver noise figure	4 dB
CNR requirement	11 dB
Optical Parameters	
Laser output power	0.5 mW
Laser RIN	-122 dB/Hz
Max OMI of laser	0.25
Photodiode responsivity	0.6 W/A
Fibre Length	50 m
Fibre attenuation	2.5 dB/km
1 x 4 splitter loss	8 dB

The analysis predicted that an optical power of > -17dBm is required at the receiver in order to achieve a CNR of 11 dB at the system's output, which would allow error free reception of all current satellite TV broadcasts. With the assumptions shown in the table and for the optically split system architecture shown in Figure 12, the received optical power would be -11 dBm, leaving an optical margin of 6 dB thus demonstrating that robust transmission over the link could be achieved. This result is shown graphically in Figure 8 which shows the calculated dependence of the output CNR on the received optical power.

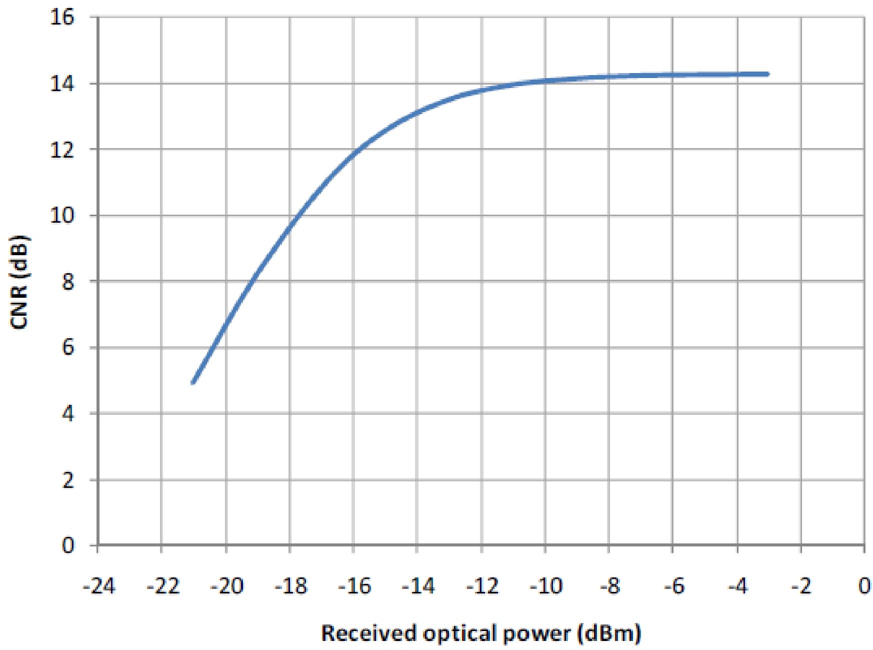


Figure 8   Calculated CNR as a function of received optical power

The impact of laser noise (RIN) and the drive level applied to the laser are shown in Figure 9. The results in the figure indicate that if the laser RIN is below -122 dB/Hz it results in a system penalty of less than 1 dB penalty. The RF drive level applied to the laser is also a critical factor affecting the system's output CNR, with high drive levels giving better performance. This is also shown in the figure, where the system margin is plotted as a function of the RF drive, which is indicated as the optical modulation index (OMI). OMI is the RF modulation applied to the laser expressed as a percentage of its dc bias, and the figure suggests that an OMI of at least 0.18 is required to achieve the 3dB margin required for reliable transmission. The figure suggests that increasing the OMI further and further will improve the link's performance, however this improvement will be limited in practice by the intermodulation distortion that occurs within the laser at high modulation indices, an effect which has not been included in this analysis.

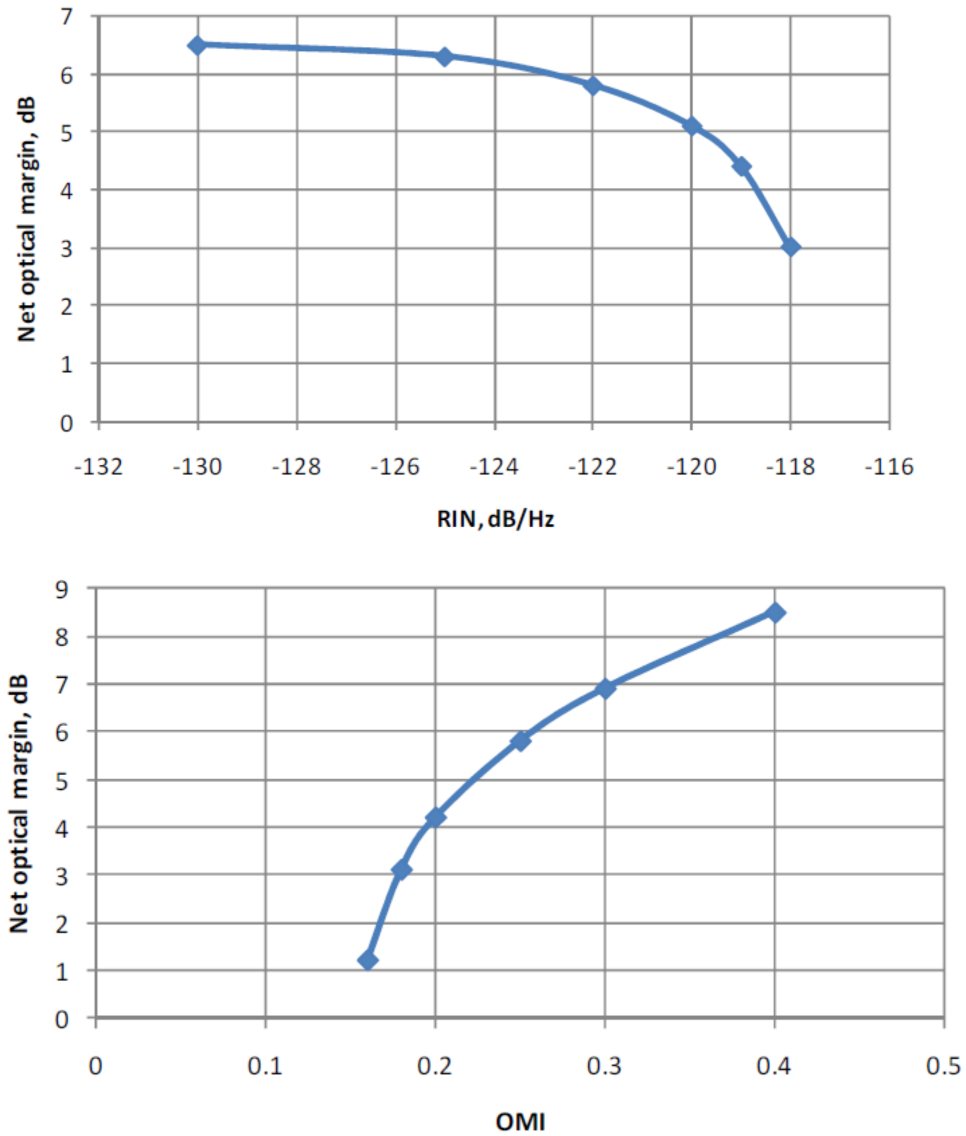


Figure 9 Optical margin as a function of RIN and OMI

To confirm these link performance predictions a system test was undertaken with a VCSEL laser being driven by the signals from an LNB receiver mounted on a satellite dish. The VCSELs output was connected to a photodiode via a variable optical attenuator, and the output from the photodiode connected to satellite TV meter to monitor the signal quality. Figure 10 shows how the modulation error ratio (MER), a parameter closely related to the CNR, varied as the RF drive to the laser to the laser was varied. The results show that there is an optimum range between -35 and -25 dBm, below which the MER is degraded owing to the low received signal level, and above which is degraded as a result of intermodulation distortion generated in the laser.

Figure 10 MER penalty measured as a function of laser input power for transponder channel T9

In addition to looking at the effect of the RF drive to the laser, the impact of optical loss and laser RIN were also investigated. Figures 10 and 11 confirm that the minimum received optical power of -17 dBm predicted theoretically is consistent with experiment. All the results obtained were in reasonable agreement with the theoretical predictions and thus validated the system model.

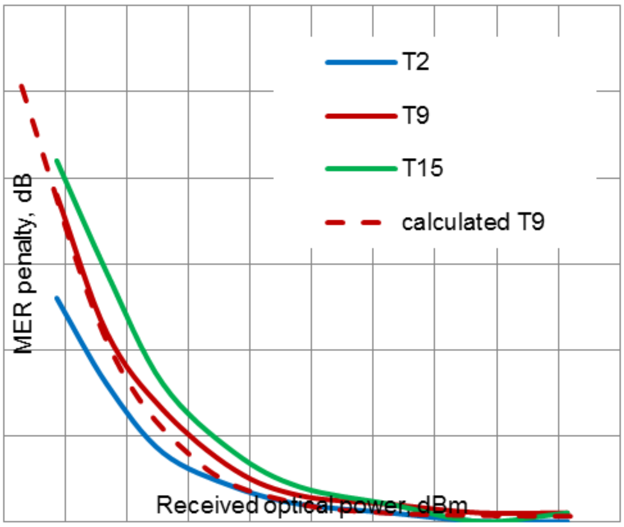


Figure 11 MER penalty as a function of received optical power for transponder channels T2, T9 and T15. Also shown is the calculated penalty for T9 (dashed line).

System Modules

Having defined the specifications for the optical components, identified suppliers and undertaken initial link tests confirming the viability of the approach, the design, assembly and testing of the transmitter and receiver modules was undertaken.

Transmitter and Receiver Modules

Two approaches were considered for the design of the transmitter module [9] and are depicted in Figure 12 below. One of these employs RF splitting to provide the RF drive signal to 16 lasers, each of which connects directly to one of the four viewing locations, thereby providing the four bands to the four viewing locations. The alternative approach uses four lasers, with the output of each of these split four ways using a 1 x 4 optical splitter, to produce the required 16 outputs necessary to deliver the four bands to the four viewing locations. The figure shows the transmitter module's signal path for just one of the four satellite bands, and so would be replicated four times in order to provide a fully functional module. The RF split version of the module therefore require 16 VCSEL lasers, whereas the optical split version only requires 4 lasers together with four 1 x 4 optical splitters. At the time this work was undertaken it was unclear as to which approach would perform best and offer the lowest cost, however subsequently it was concluded that the cost of the four optical splitters outweighed that of the extra lasers, and the RF splitting approach is now considered to be the favoured option. Prototypes of both designs were fabricated and used in the system demonstrators and field trials.

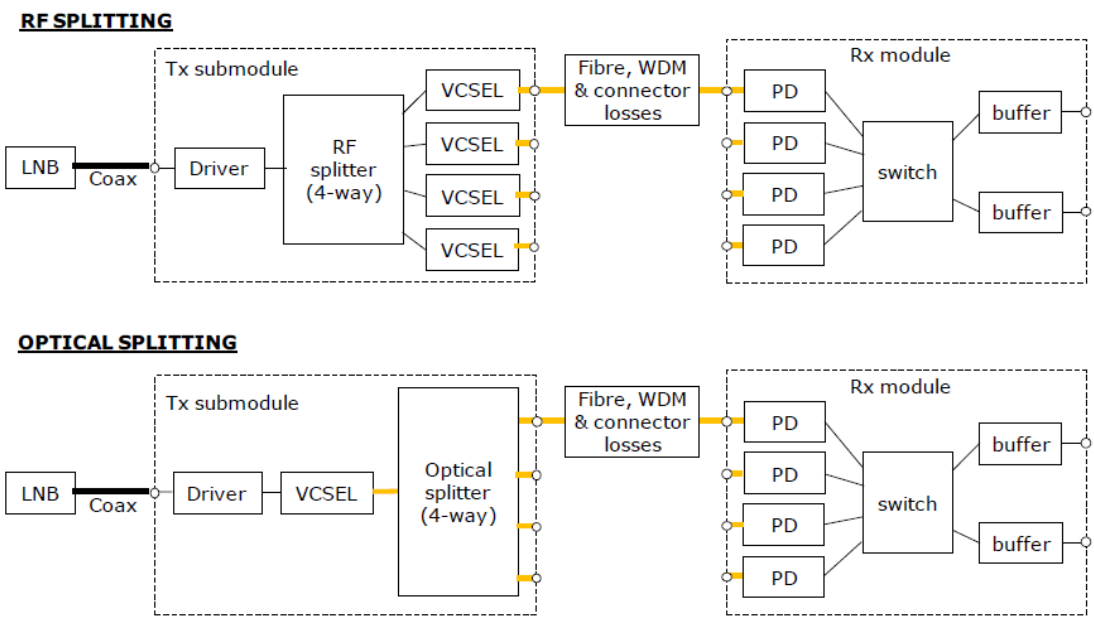
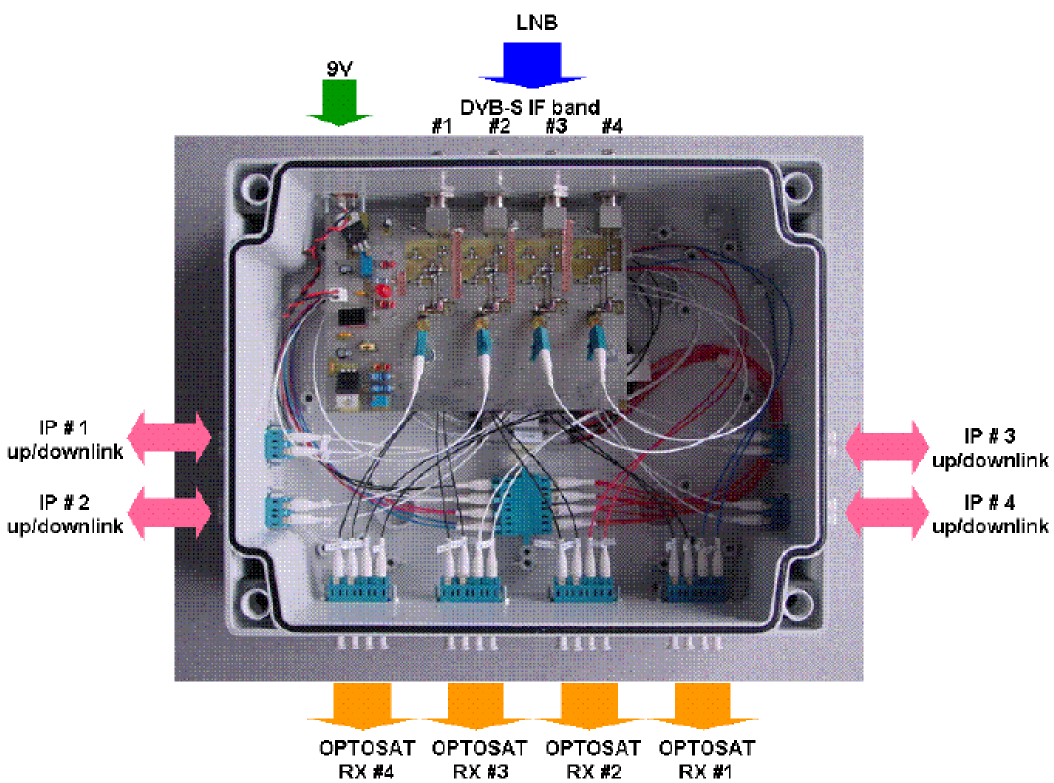


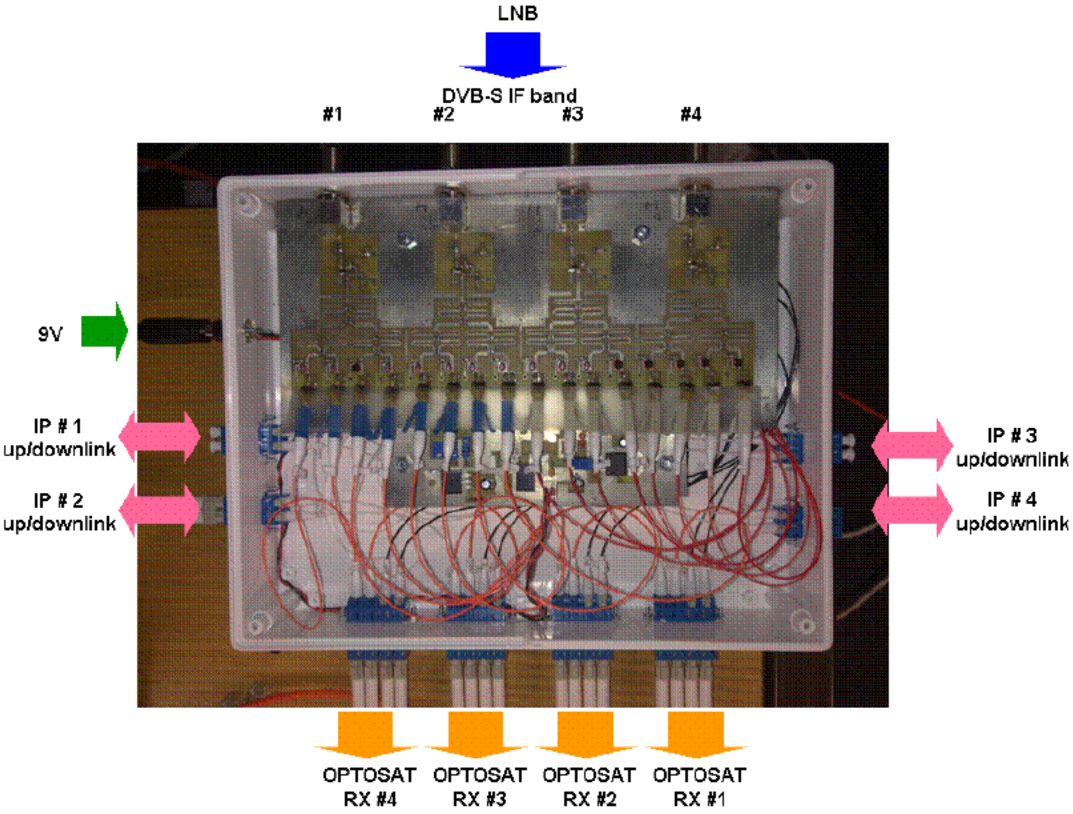
Figure 12 System design with different transmitter design options

Photographs of two prototype transmitter modules, one using optical splitting, the other RF splitting, and of one receiver module are shown in the figures below [10]. These units were designed with a view to easing the tasks of modifying the PCBs during the debug and optimisation phase, rather than to minimise their size and cost as would be the case for the final product. There is therefore considerable scope for size reduction through the optimisation of the PCB layout, routing of the optics, and choice of housing, however the units produced were entirely suitable for evaluating the functionality and viability of the concept and the components used, an example of which is shown in Figure 14. This figure shows a measurement of the system's frequency response using the prototype modules connected via a length of multimode fibre. The overall gain is close to unity, so any receiver connected to the system will receive signal levels as if it were connected directly to the LNB. Considerable gain slope is present across the band, and this was subsequently found to be caused by parasitics associated with manner in which the lasers and detectors were mounted on the PCB. This was considerably improved later by mounting these parts in a more optimal manner, and is not considered to be a limitation in the system's overall capability.

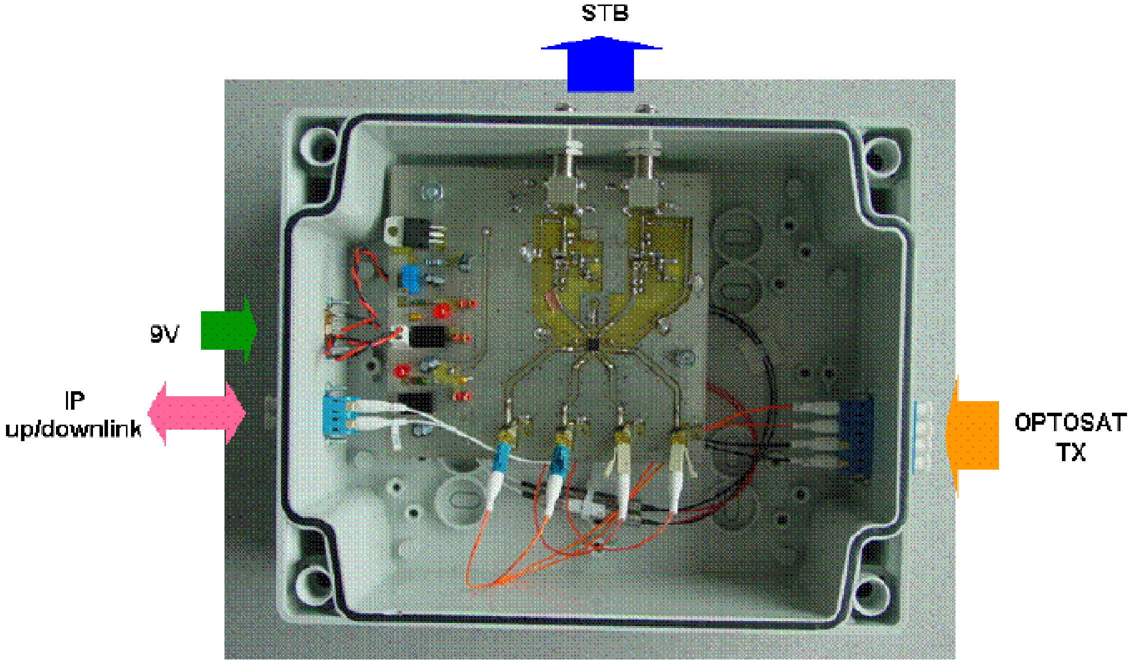
In total four transmitters and receiver modules have been fabricated, and these have been used in the system demonstration and field trials described later.



TX prototype using optical splitting scheme (fibre optics based)



TX prototype using electrical splitting scheme (fibre optics based)



RX prototype (fibre optics based)

Figure 13 Photographs of assembled Optosat modules

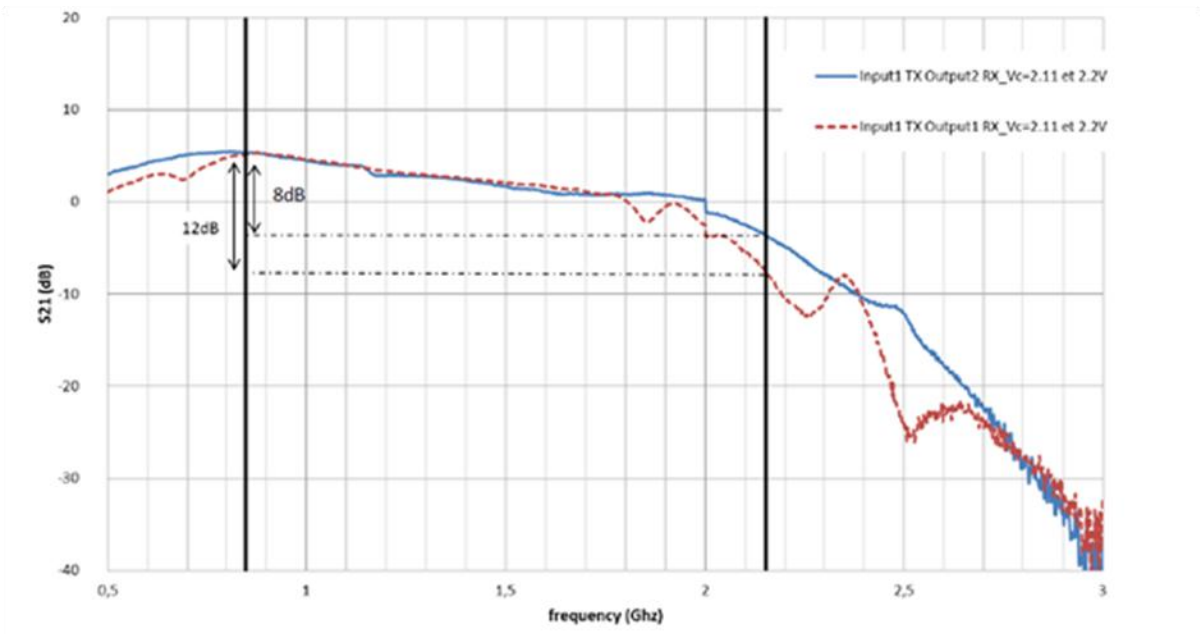
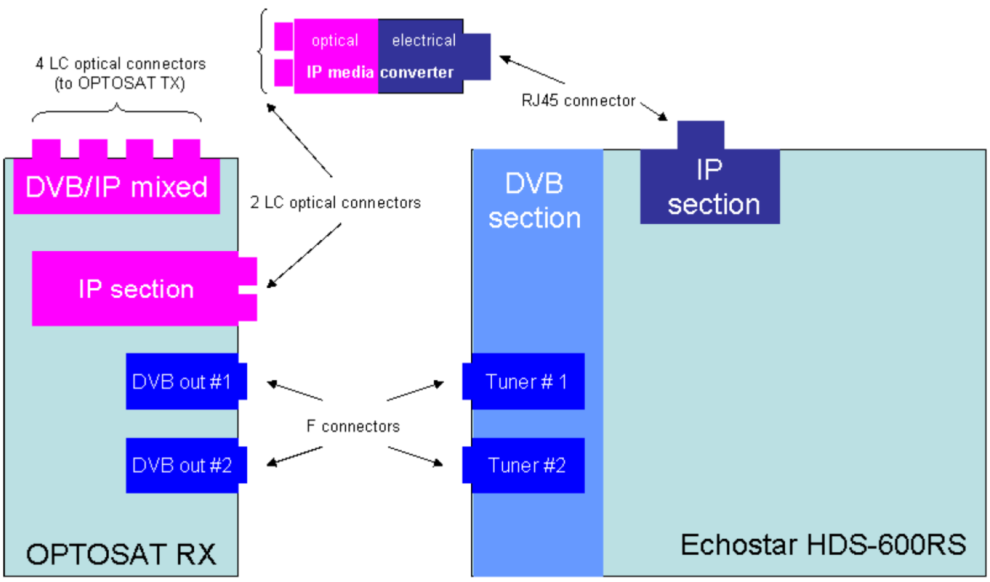
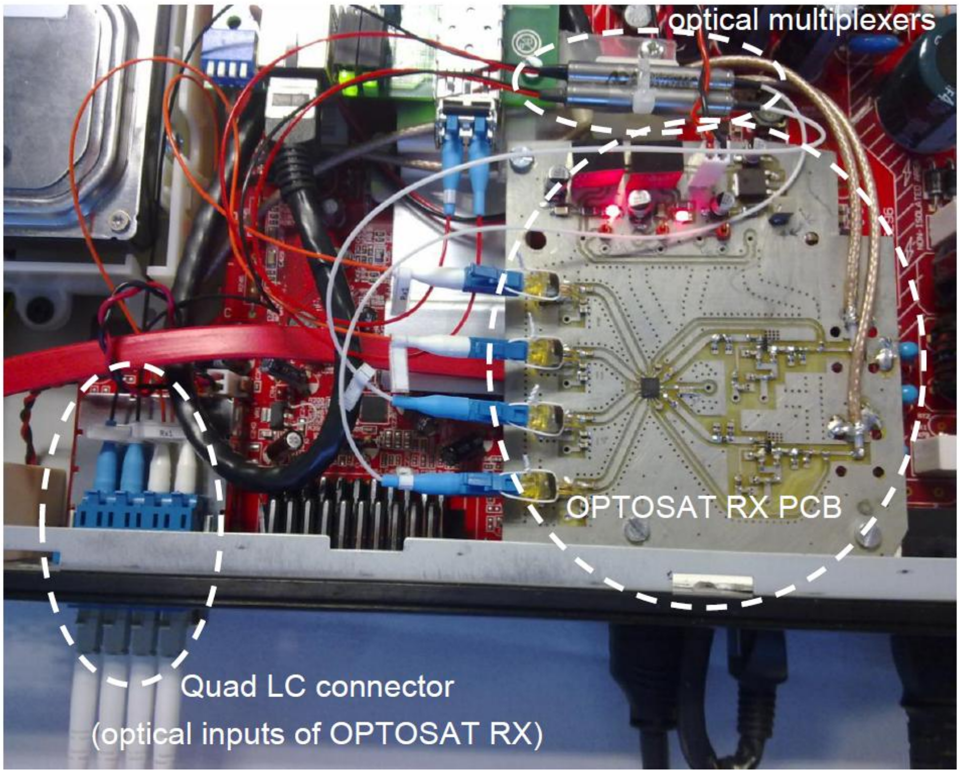


Figure 14 Frequency response of an Optosat transmitter receiver pair

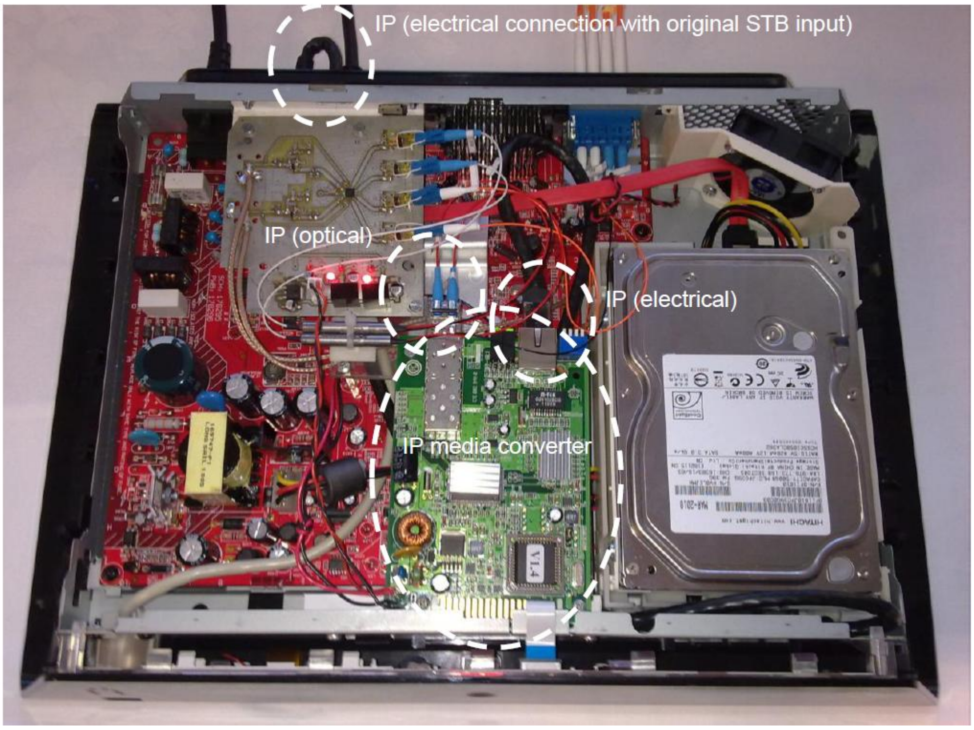
In addition to the standalone transmitter and receiver modules described above, the receiver circuitry was also integrated into a commercially available set top box [11], a twin tuner EchoStar HDS 600RS, thus converting the unit into a fully functioning Optosat system receiver as shown in Figure 15 below. The figure shows the architecture and photographs of the Optosat PCBs mounted in the STB. The scheme also required the inclusion of an IP media converter to interface the Optosat receiver's IP optical output to the STB's electrical input. The unit was fully functional, and was used in the system demonstrator and field trial.



Architetcure of STB with integrated Optosat receiver



Photgraph of STB showing Optosat receiver PCB and optical inputs



Photgraph of STB with integrated Optosat PCBs

Figure 15 Block diagram and photographs showing the STB with integrated Optosat receiver circuitry, and showing the unit used to display live TV signals

System Demonstrator and Field trials

A demonstration system was assembled in one of the project partner's offices [12], using these prototype units, and emulating what was considered to be a likely installation in a single family home. The set up, illustrated in Figure 16, comprised a quatro LNB mounted on a dish, connected to the Optosat transmitter module via four coaxial cables. The actual cable run used in this demonstrator was significantly longer than would normally be the case and some slope compensation was included to allow for the greater attenuation at higher frequencies, which was significant for this cable length. In a practical SFH installation the coaxial cable run to the transmitter module would only be a few metres and slope compensation would not be required.

The four sets of outputs from the transmitter module were used to feed four zones within the demonstration room, each zone being equipped as follows:

Zone 1	Zone 2	Zone 3	Zone 4
- LCD TV	- LCD Monitor	- LaCie Cinema HD	- PC with DVBS Rx card
- Humax HDR STB	- Humax HDR STB	- LCD Monitor	

Figure 16 below shows a photo of one of the zones in operation with the TV displaying one of the satellite channels being received from the same satellite dish as the other zones over the Optosat network.

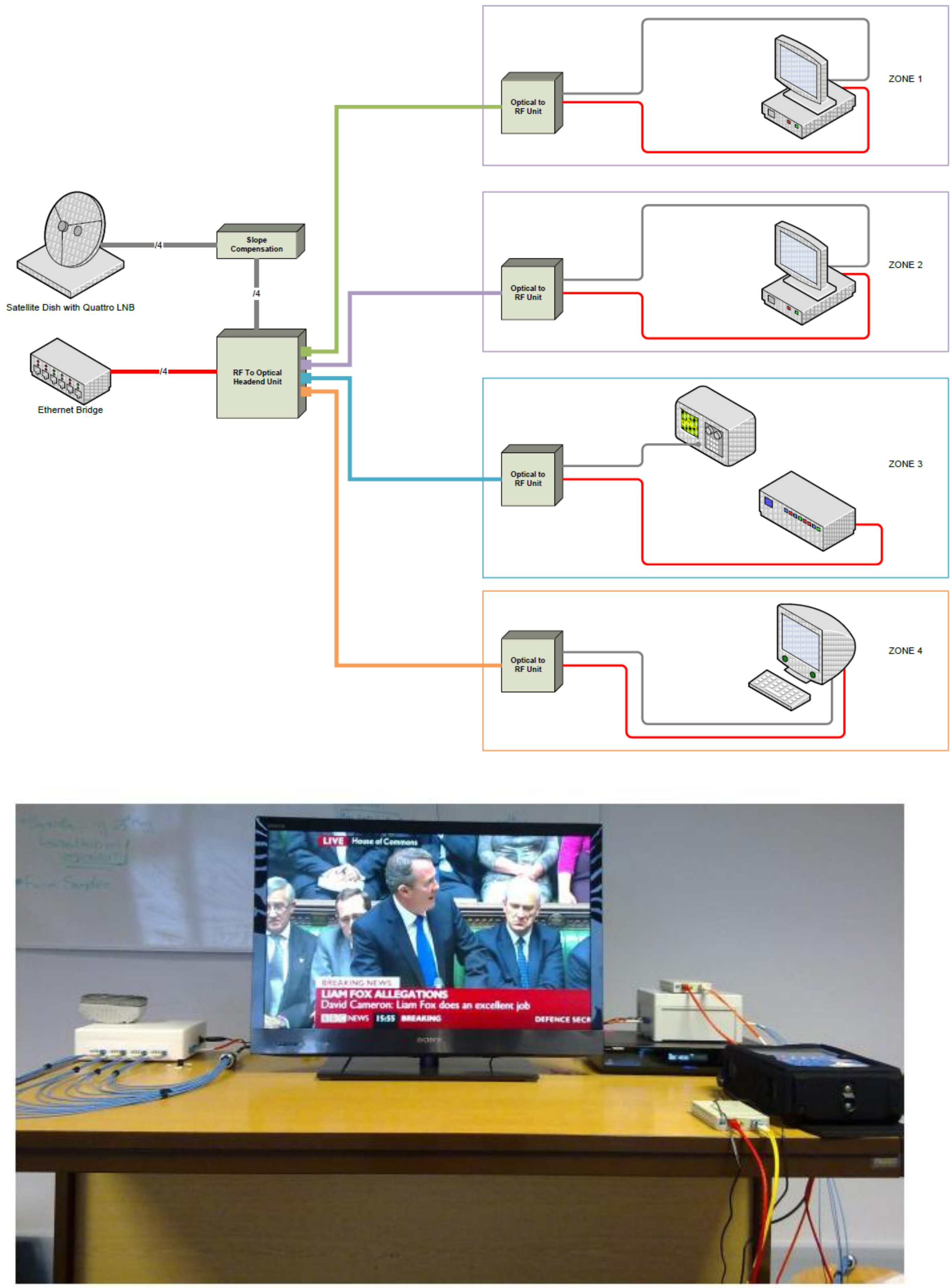


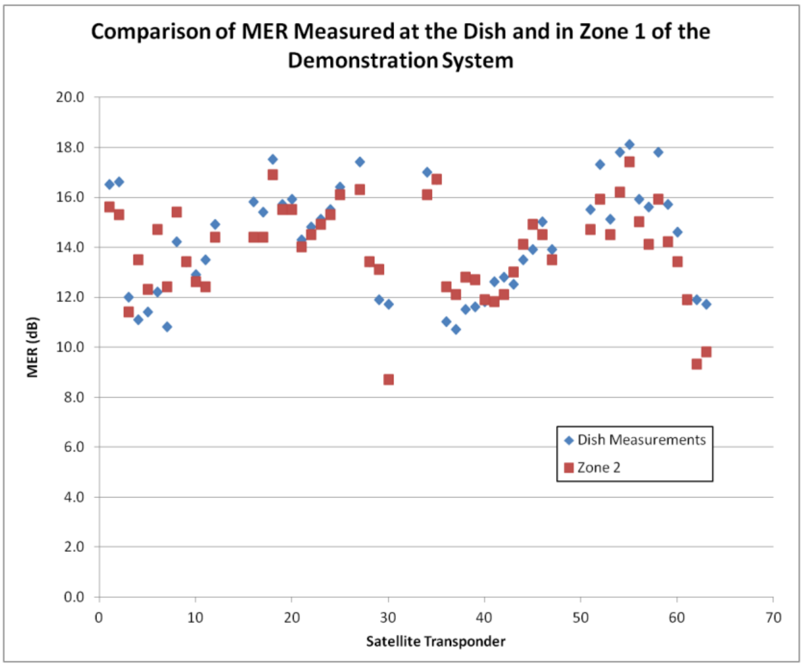
Figure 16 Block diagram of demonstration system and photograph of one viewing location in operation

In addition to viewing the TV channels broadcast from the satellite, a TV meter could be connected at any of the viewing locations, which allowed a quantitative assessment of the of the signal quality. To assess the overall performance of the system the signal quality was first assessed at the satellite dish before transmission over any coaxial cables or the Optosat system. These measurements were then repeated at the viewing locations, and the results compared with those taken at the dish to evaluate the impact of the system on the signal quality. A commonly used figure of merit for the quality of a broadcast digital TV signal is its MER, which is closely related to the CNR and is one of the parameters reported by the TV meter.

Figure 17 compares the MERs measured in Zone 1 with those measured directly from the LNB. The results show that there is little difference between the measurements, the exceptions being at the highest frequencies within some of the bands, and this attributed to the roll of in the system's frequency response at these frequencies. As discussed above, this roll off is associated with mounting of the lasers and detectors within the modules and will be straightforward to rectify when developing the final product, and is not considered to be a limitation in the systems capabilities.

A comparison of the MERs obtained after transmission over 10 and 70 metre lengths of fibre is shown in Figure 17, and as expected there is no significant difference in the performance seen, thus demonstrating that the long lengths of fibre may be used without any discernible effect on system performance.

In addition to the testing undertaken on the satellite TV reception, Ethernet data connectivity over the system was demonstrated by connecting a PC to the Optosat system at one location and using it to access the internet, and also by streaming content from the LaCie Cinema to one of the other zones.



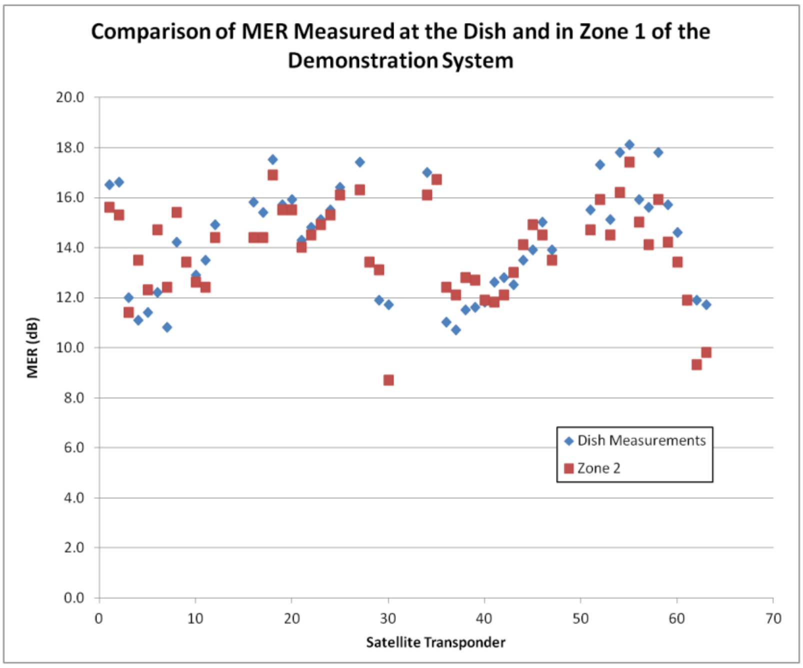


Figure 17 Demonstration system MERs showing the impact of the Optosat system on signal quality and the affect of increasing the fibre length

Having assessed the performance of this demonstrator, a field trial was undertaken using these prototype Optosat modules. The system was installed in a domestic residence in Spain, and the overall performance of the system was found to be very similar to that seen in the demonstration set up.

Conclusion

This project has succeeded in identifying a low cost architecture for the distribution of DVB satellite TV signals based on optical fibre technology, using low cost optical components and multimode optical fibre, all of which are mass produced for the datacoms market. The project has shown that these components, which are designed for use in digital systems, are also suitable for use in analogue applications such as this, thus enabling a cost reduced solution to be realised. The project has built prototype transmitter and receiver units, also integrating this receiver circuitry into a commercial satellite receiver, and has used these to build a system demonstrator and successfully undertake field trials. In addition to this, the project has demonstrated that the approach can be extended to provide IP data connectivity between the viewing locations in the home, which apart from providing internet access, would also allow play back of material stored on one STB by streaming it over this data connection to another viewing location in the home.

4. The potential impact and the main dissemination activities and exploitation of results

The impact and results of the project will be exploited by generating a new range of products based on the results of the research with the product form, function and price being led by market need. It is proposed that these new products are an extension to the existing Global Invacom Fibre MDU Range to cover some of the areas of the market that are not addressed by the current product range.

GIL was the first company in the world to develop a range of low cost Optical Fibre based products for the high volume DBS market, these products have been very successful for the company and have generated significant year on year sales growth and revenues.

In Europe the MDU market only represents around 10% of the overall DBS market, it is the other 90% that the OPTOSAT project was aimed at. These new products will utilize components based on the specifications generated within the project in order to generate a means for each of the industrial partners in the project to benefit from the potential supply of these parts. With an annual market size of over 30M units for Europe alone this presents a major market for the technology generated within the project.

The sales of the finished products by GIL to its existing customer base and the sales of parts to GIL by the consortia partners will generate new sources of revenues for each of the partners and countries involved in the project. These sales will continue on an annual basis for three to four years, before a new generation of products and components are required.

The impact of this new technology on the wider European community will be to enable a wider deployment of Satellite TV technology into new areas. One of the main limitations in the past that has restricted the general deployment of Satellite TV has been the complexity of Satellite TV installations in homes requiring more than one STB. This often results in most homes only using Satellite TV in one viewing location and relying on Terrestrial TV for the second viewing location. With OPTOSAT this limitation is reduced as the installation of the second third and fourth box installation is much easier using this new technology than traditional IF switch systems. This will enable countries to transfer more of its TV services to Satellite, freeing up the valuable Terrestrial Spectrum for other new services such as LTE

At the end of the project the demonstration system was presented to the team in a major European Broadcaster responsible for introducing new technology. The demonstration was successful and well received as being in line with the needs of the Broadcaster, as a result of this a follow up demonstration has been requested in order to present the technology to a wider audience, including the engineering team. We are currently in the process of moving the demo system to the Global Invacom office in Stevenage in order to facilitate this demonstration.

5. Project portal

Project website address: www.optosat.com

USE AND DISSEMINATION OF FOREGROUND

6. Section A - For Public Domain

DISSEMINATION STRATEGY

The primary aim of this dissemination activity is to engage with the DBS market early on so that the benefits of the system are widely understood ahead of any commercialisation of the system. The success of subsequent marketing efforts will depend on initiating and maintaining contact with this group before turning them into users, distributors or installers of the system.

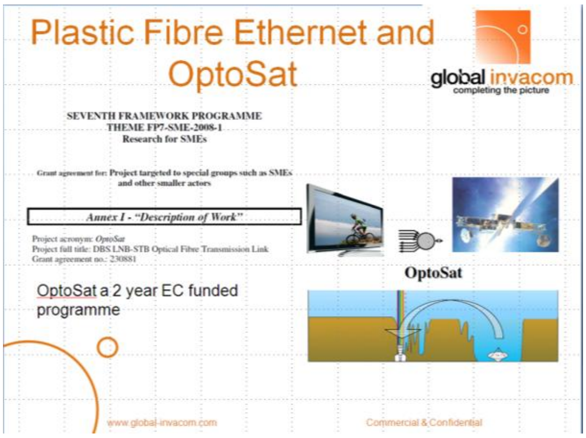
A secondary goal is to raise awareness of the scientific advances made during the project so that contact may be established with other organisations and individuals working in the field, as well as the general public.

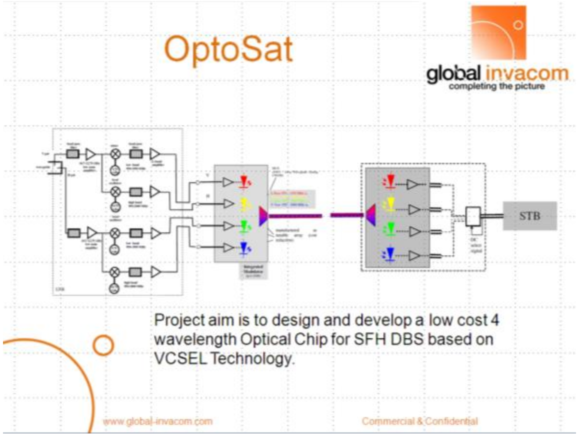
Finally, the benefits of the system need to be tailored and communicated effectively for different groups of users ranging from those with little knowledge of the technology through to the main DBS broadcast organizations.

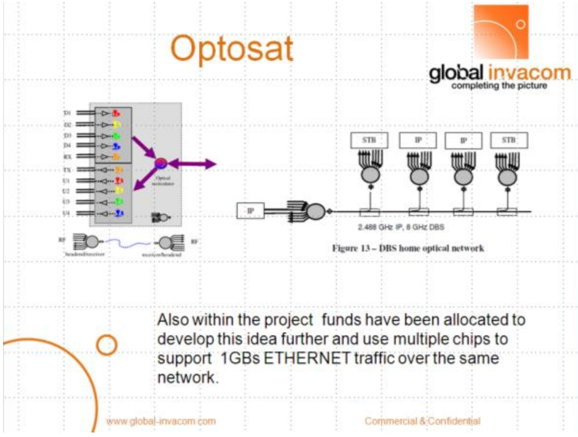
As part of our process of informing our customers of developments within R and D we have been publicising the objectives and status of Optosat to key customers for the last two years, this has resulted in interest from a number of our current customers.

One example of this being the following selected content from our standard customer presentation regarding our Optical Fibre Technology, this has been presented by the sales team on numerous occasions to multiple key OEM customers

It is our aim to continue with this general dissemination of information from the project, once this initial phase has completed we will switch to a customer specific approach that will coincide with the start of product development for each particular market and customer.







Further community engagement will also come through a website purpose built to inform, engage with and establish direct contact with the DBS community. It will also be used as an interactive tool to get direct feedback into the project via email.

Awareness of the functional and technical achievements of the project will be raised with the user and scientific community through attendance and presentations at appropriate conferences and events.

TARGET AUDIENCE

The intended audience for any dissemination activity is made up a number of different groups, each with different informational requirements:

- ☐ Prime users – OEM Broadcasters.
- ☐ Secondary users – system installers and distributors in the DBS market.
- ☐ End Customers – Final users of the technology
- ☐ Research Organisations
- ☐ Standardisation bodies
- ☐ Policy makers

The dissemination plan will take their different needs into account and ensure that these are met through appropriate activities.

COMMUNICATION CHANNELS

Dissemination of the project and its results will take place through a number of channels deemed appropriate for this early stage of development. This will include the publication of technical papers in journals regarding some aspects of the technology. This will provide a means for the research partners to promote their capability to the wider community.

Global Invacom regularly has its technology reviewed in industry publications, we use this a direct means of publicising our capability and as a channel for rapid customer feedback to a new product launch.

An example of this is the article on our original fibre system carried by Tele Satellite and Broadband Magazine.

7. Workshops Demonstrations Exhibitions and Seminars

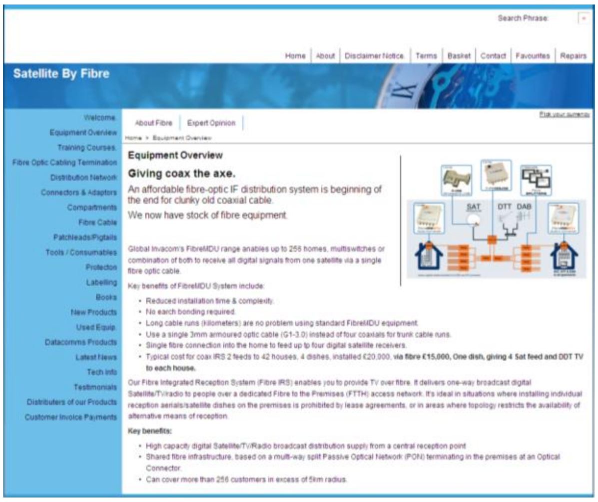
Global Invacom carries out a continuous program of workshops, customer demonstrations and seminars. Each year we have a promotion stand at least five major trade shows around the world where as well as general product promotions on the main stand selected customers are introduced new technology on a one to one basis.

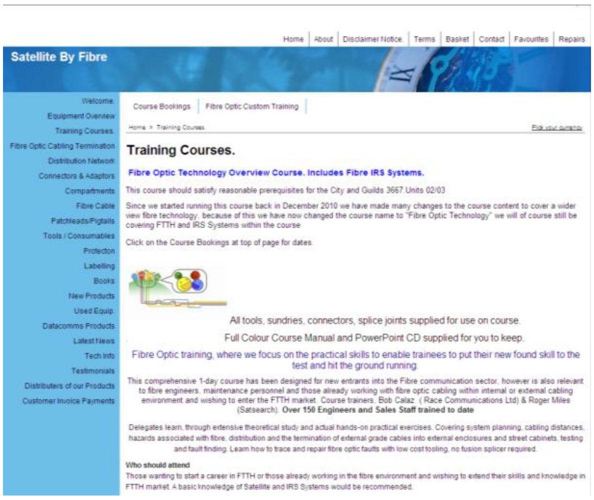
Our workshop training programs are also a regular event in order to promote new products to installers and distributors. Typically these will be carried out by our technical support staff and will involve a one to two day training program for an audience of 20-40 customers. In a typical year 20 of such workshops are carried out with suitable promotion and training materials being generated for general distribution to attendees.

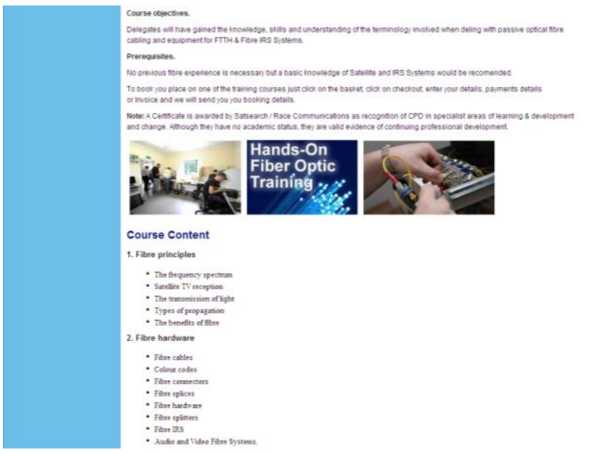
It is expected that products resulting from the Optosat project will be promoted in a similar fashion along with other products in our current Fibre MDU range.

In addition to this demonstrations are carried out at key customer premises throughout the year, these are initiated by the sales team as part of their ongoing program of product promotions to major customers.

As part of this process the key outcome from the Optosat project was the demonstration system. Global Invacom has begun a program of inviting key customers to view the technology in action. This process has already started and sales are currently investigating the logistics of further demonstrations.







Above is an example of the training now on offer in the use of Global Invacom Fibre IRS Systems, these courses are run by an independent company and have proved popular with installers. The syllabus of these training events will be extended to cover the technology developed within OPTOSAT.

http://www.satellitebyfibre.co.uk/contents/en-uk/d151_training.html

Other members of the consortia have also begun the process of presenting components developed as part of the project at exhibitions and trade shows. For example CUBO presented an early stage pre-prototype of the Optosat Mux and Splitter at the OFC show at their booth in LA in March (8-10), 2011.

http://www.ofcnfoec.org/home.aspx

The final versions of the Optosat Mux and Splitter were shown at the ECOC show at the CUBO booth in Geneva in September 19-21, 2011

http://www.ecoc2011.org/

8. Website

A website has been developed for the project which can be found at http://www.optosat.com

9. Conferences

Papers and Display Posters will be submitted to the following conferences, which will also present networking opportunities with professionals and potential users of the OPTOSAT technology. Some of these conferences are non-academic and are usually included as part of a trade show and should lead to further engagement with the target customer base.

2011 European Microwave Conference - Manchester from 9 to 14th October 2011

- Target Audience: Professionals in RF and Microwave fields of research.
- http://www.eumweek.com

2012 FTTH – Fibre to the Home Conference and exhibition - Munich from 14 to 16th February 2012

- Target Audience: Professionals in Optical Fibre Networks.
- http://www.ftthcouncil.eu

Satellite 2012 – Satellite and VSAT Conference and Exhibition - Washington from 12 to 15th March 2012

- Target Audience: Professionals in Satellite TV Networks.
- http://www.Satellitetoday.com/satellite2012

IBC 2012 – Satellite TV and VSAT Conference and Exhibition - Amsterdam from 6 to 11th September 2012

- Target Audience: Professionals in Satellite TV and Data Networks.
- http://www.ibc.org
- Status – Display Poster in Preparation for exhibition stand

2011 European Microwave Conference

10. Publications

Articles will be prepared and submitted as well as samples supplied for technical review to the following publication:

Tele Satellite and Broadband is the premier international, interdisciplinary journal of Satellite TV, DTT, IPTV and 3DTV. It publishes on a monthly basis since 1981 in over 20 languages and is read in over 170 countries around the world with a readership in excess of 350,000. It carries regular technical reviews of new products as well as new ideas scholarship and information and serves as a forum for the exchange of ideas, airing of controversies, and discussion of issues. It has a worldwide readership in the industry from all sectors. Global Invacom has been awarded several Innovation Awards by the magazine over the years for its products and is in regular contact with the publication.

11. Section A (Public)

Table A1: list of scientific (peer reviewed) publications, starting with the most important ones										
NO.	**Title**	**Main author**	**Title of the periodical or the series**	**Number, date or frequency**	**Publisher**	**Place of publication**	**Year of publication**	**Relevant pages**	**Permanent identifiers[3] (if available)**	**Is/Will open access[4] provided to this publication?**
1	Radio over Fiber Links for Home Distribution of Direct Broadcast Satellite TV Signals.	David Wake	Journal of Lightwave Technology	TBD		UK	*2012*			Will

[3] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[4] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

Table A2: list of dissemination activities								
NO.	**Type of activities[5]**	**Main leader**	**Title**	**Date**	**Place**	**Type of audience[6]**	**Size of audience**	**Countries addressed**
1	Conference	UoL	2011 European Microwave Conference - Manchester	October 9-14 2011	Manchester	Industry	> 5000	UK
2	Conference	GIL	2012 FTTH – Fibre to the Home Conference and exhibition	14 -16th February 2012	Munich	Industry	> 5000	GERMANY
3	Conference	GIL	Satellite 2012 – Satellite and VSAT Conference and Exhibition	12 to 15th March 2012	Washington	Industry	> 5000	USA
4	Conference	GIL	IBC 2012 – Satellite TV and VSAT Conference and Exhibition	6 to 11th March 2012	Amsterdam	Industry	> 5000	NETHERLANDS

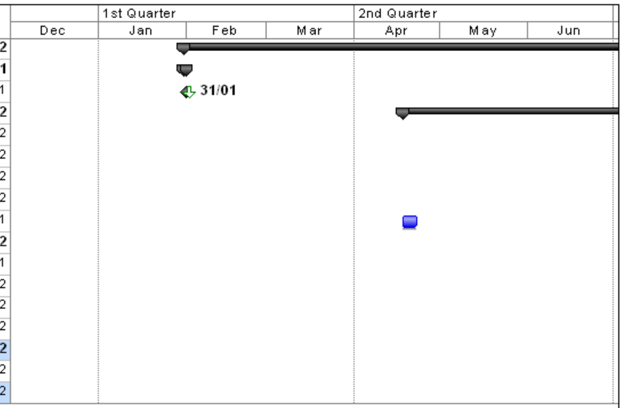
[5] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[6] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

TIMING PLANNING

The Gantt chart showing the schedule of dissemination activities is shown in below.

ID		Task Name	Duration	Start	Finish
1		**OPTOSAT Dissemination Plan**	**423 days**	**Mon 31/01/11**	**Wed 12/09/12**
2		**Website**	**1 day**	**Mon 31/01/11**	**Mon 31/01/11**
3		Launch	1 day	Mon 31/01/11	Mon 31/01/11
4		**Customer Demonstrations**	**245 days**	**Mon 18/04/11**	**Fri 23/03/12**
5		System Available	1 day	Mon 02/01/12	Mon 02/01/12
6		Demonstration 1	5 days	Mon 16/01/12	Fri 20/01/12
7		Demonstration 2	5 days	Mon 20/02/12	Fri 24/02/12
8		Demonstration 3	5 days	Mon 19/03/12	Fri 23/03/12
9		Demonstration 4	5 days	Mon 18/04/11	Fri 22/04/11
10		**Conferences and Papers**	**243 days**	**Mon 10/10/11**	**Wed 12/09/12**
11		European Microwave Conference	5 days	Mon 10/10/11	Fri 14/10/11
12		2012 FTTH Conference and Exibition	3 days	Tue 14/02/12	Thu 16/02/12
13		Satellite 2012	4 days	Mon 12/03/12	Thu 15/03/12
14		IBC 2012	5 days	Thu 06/09/12	Wed 12/09/12
15		**Publications**	**45 days**	**Mon 30/01/12**	**Fri 30/03/12**
16		Journal of Lightwave Technology	1 day	Mon 30/01/12	Mon 30/01/12
17		Tele Satellite and Broadband	1 day	Fri 30/03/12	Fri 30/03/12



12. Section B Confidential

EXPLOITATION STRATEGY

The market sectors of the companies in the OPTOSAT project are separate and non-conflicting and they all stand equally to gain from a successful project. The proposed means that this will be achieved based on the current status of the project and its potential outcome is described in this document. However it should always be considered that the Satellite TV market is a dynamic one and hence each individual company's strategy will need to adapt to changes in the market, as a consequence this plan will also need to adapt. This is therefore a working and fluid document.

To access the market a dynamic satellite system installer with regional government contracts in Spain has been recruited to the consortium to provide initial trials data and feedback on the prototype display system. This partner has previously been involved in providing training on behalf of Campania to the installation industry across Spain and will utilize this expertise and contacts on behalf of the OptoSat consortium.

It is also the case that in other regions and countries that each partner has established routes to market that will also be exploited as a result of the technology developed within this project.

For example the coordinator Global Invacom has strong links as a supplier to BSkyB in the UK. We have therefore included BSKyB on this diagram as an example of a service provider as Invacom has a established commercial link as a major supplier of equipment to BSkyB. This link has been exploited and an initial demonstration has been carried out, a follow up to this is now planned.

There are also strong existing commercial route links between some of the SMEs and these end users and the consortium fits together well, providing the SMEs with clear exploitation routes.

The aim is to fully commercialise the OptoSat technologies as soon as results from the project are available, and the IPR is fully secured. IP will be distributed to and jointly owned by the relevant SME participants and subsequently controlled by the Exploitation Manager. IP rights have been clearly formulated in the 'Consortium Agreement' signed by all the members of the consortium prior to Project Start.

This Consortium Agreement allocates the ownership of the IPR to provide a practical and immediate industrial focus, and ease the legal and administrative issues of patent ownership. The main innovations in the project, as listed in the table below, will be protected by means of patents, and prepared for licensing.

For SMEs outside the project consortium, the only options available will be for further research or purchasing of licences which will be dictated by market conditions and subject to further agreement.
The principal results of our project and the major IPR recipient are:

1 RoF Sat TV Specification (Invacom currently markets RF/DBS products)
2 Integrated Laser/Diode Arrays (the main company business of Modulight)
3 RF Amplifiers (Invacom manufactures RF systems)
4 Optical Tx MUX / Recirculator (CubO's main company business)
5 Bidirectional Optical Power Splitter (CubO)
6 Integrated Bi-QOT (CubO)
7 Integrated Sat/Network Module (replacement optical transceiver for Invacom)
8 Hybrid STB (Addition to RedE's STB product offering)
9 Installation Procedures (Seyma's business area)

THE MARKET FOR OPTOSAT TECHNOLOGY

TARGET CUSTOMERS

Both MDU installers and major broadcasters from the main basis of the addressable market for the OPTOSAT Technology. The USP's for the system are summarised below

Buying Driver and USP Map

Buying Decision Maker	Buying Driver	Unique Selling Point
Multi Dwelling Unit (MDU)	Economy on infrastructure backbone	Single optical fibre has low cost
	Easy Maintenance and Reconfiguration	Simple to connect/disconnect terminals
	Big data throughput	High bandwidth offers more services/channels
Cable TV/Network installer	Easy Maintenance and Reconfiguration	Simple to connect/disconnect terminals
	Easy initial installation	Single optical fibre occupies less space in conduits
Private Customer (SFH)	Big data throughput	High bandwidth offers more services/channels

Buying Drivers and Unique Selling Points

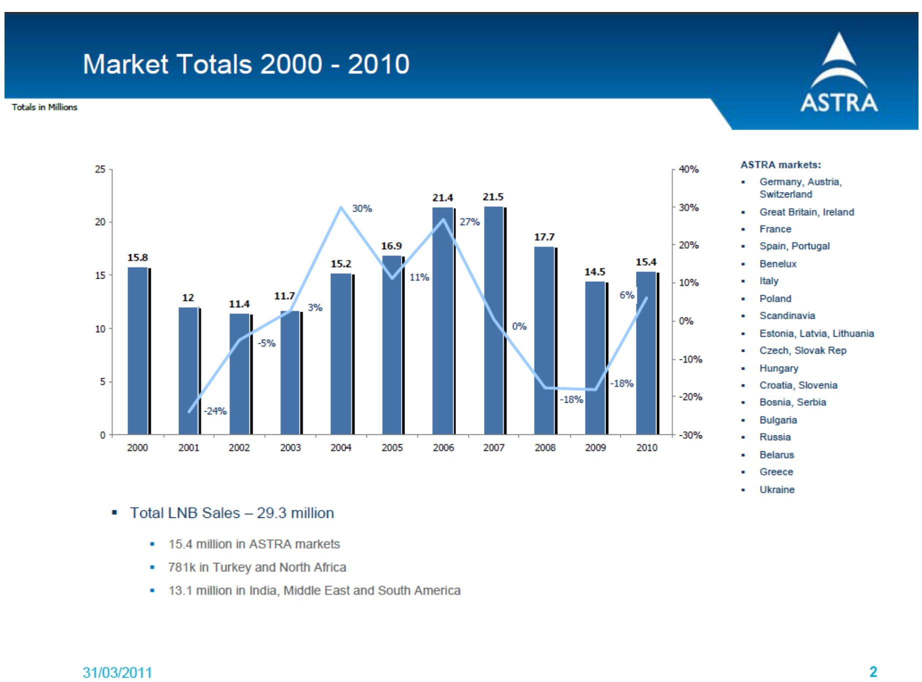
There are secondary social and environmental benefits associated with this technology including reduction of power consumption (>1 W saving per link amounting to > 100MW in total across Europe) by inefficient IF coaxial distribution networks, savings on inevitable upgrading/disposal of coaxial cables to accommodate new transmission channels and reduction of health risks to the Sat-TV installers associated with installation frequency and ground loop electric shock hazards.

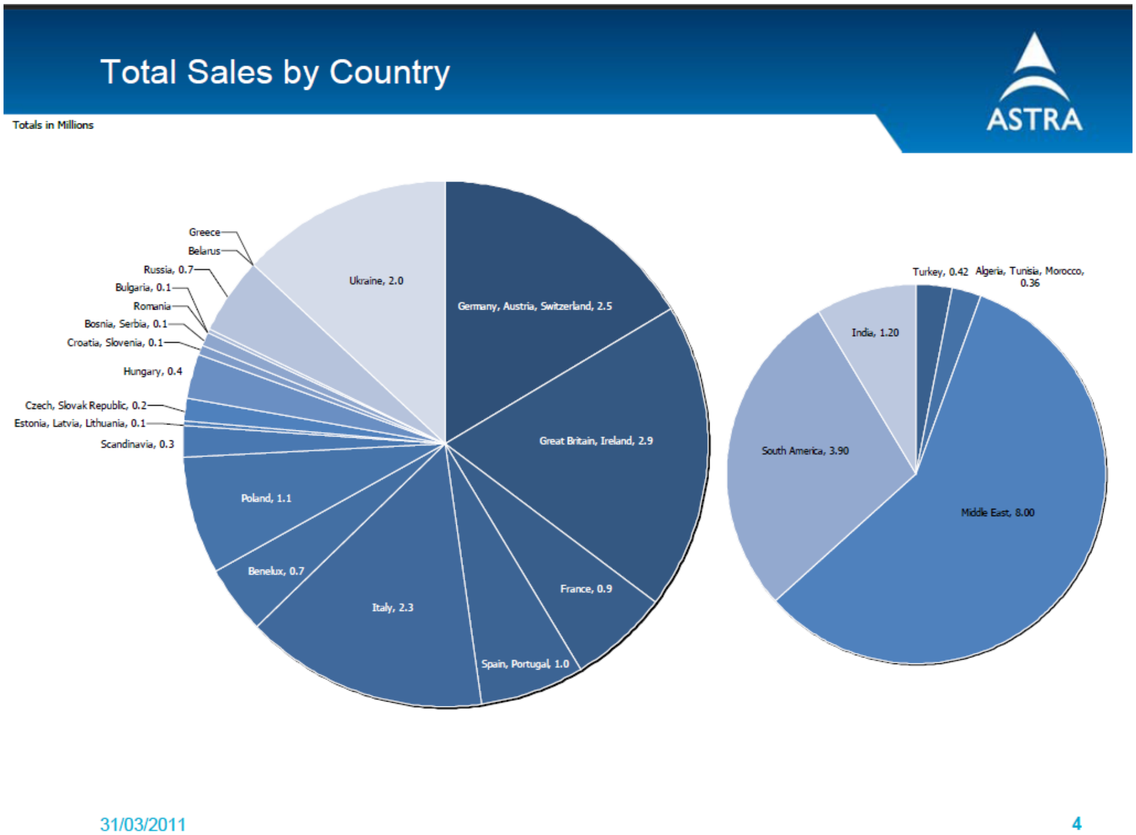
ADDRESSABLE MARKET SIZE

There are currently over 10 million UK satellite TV customers (including 4 million who have contracted for enhanced services such as Sky Plus) and the number is increasing at around 500,000 per quarter. Clearly this market will saturate but upgrades and replacement installations will ensure sales in excess of 1 million p.a. for the foreseeable future. Also most of these are individual homes rather than MDU's as until the introduction of Global Invacom Fibre technology it was very difficult to offer a comprehesive solution for MDU's.

The overall market in Europe is several times this size at present with 300 million STB's installed, with the UK dominating its European partners, but is less saturated and will continue to grow. We anticipate that the enhanced content of our upgraded optical system will be regarded as indispensable by at least 3 million UK users and will affect demand from over 2000 proffesional installers in the UK, with many others being able to carry out installations.

Using the data colated by ASTRA Europe's largest TV Broadcast Satellite operator it is clear that the overall DBS market in Europe is around 15-20M units per year.





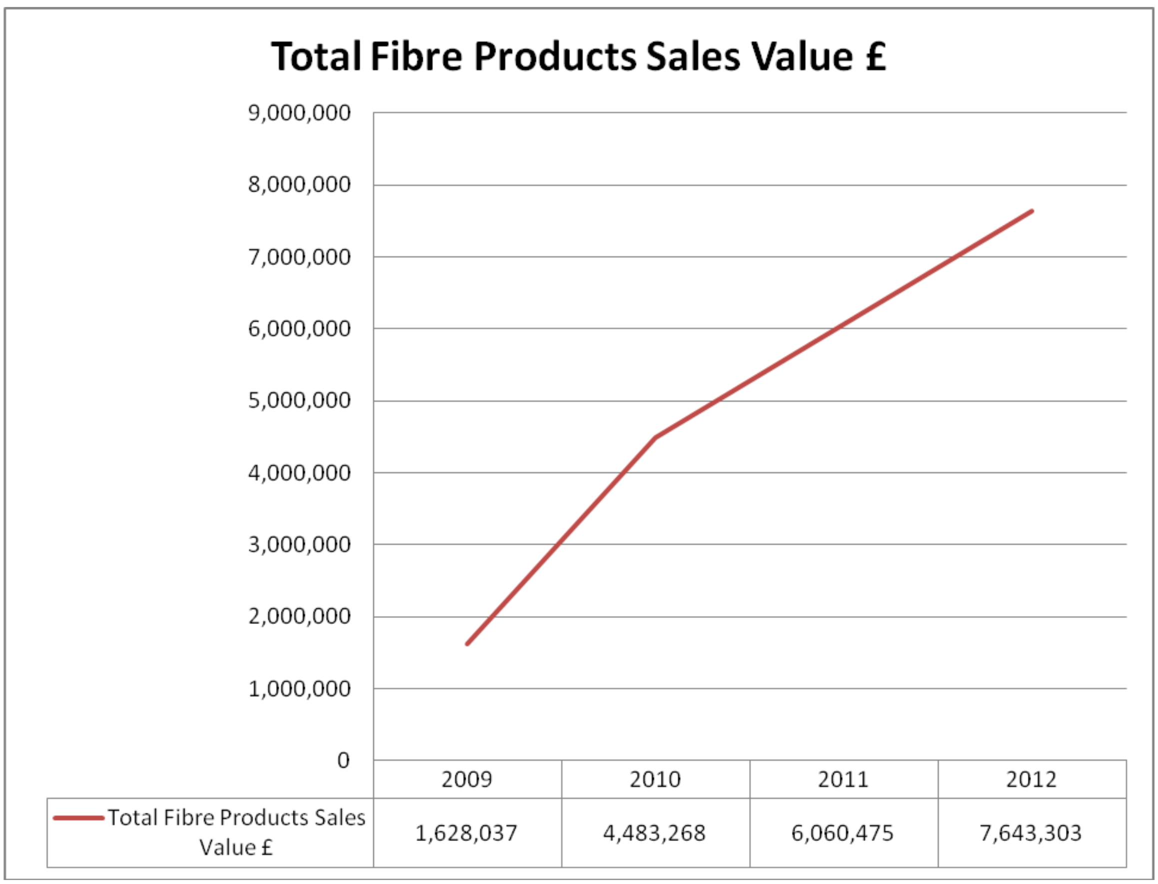
A typical single customer satellite TV installation contract costs around £200 including a one-off cost of around 10% covering the hardware. The proposed optical solution to the problem of transmission of extra channel capacity will therefore have a target price of £20-£40 for an optical module for individual use in private dwellings and more than this for residents in MDUs - hotels, apartment blocks, commercial premises, etc, where shared components in the installation will more than compensate for the higher costs of each part of the overall system.

The number of MDU systems (with at least 20 users) installed worldwide p.a. is around 1 million and many of these will supply more than 100 individual users. We predict a UK single customer market size of at least £200M merely for providing the current level of service and anticipate that the enhanced communications capabilities of this optical technology (vastly increased channels, mixed traffic, converged communications) will allow additional premiums to be charged and differentiate the providers who offer it.

Since the launch of our original MDU system in 2009 we have seen a steady increase in sales accross Europe as the system has become more widly adopted as a new standard. In the most recent months sales have reached 500K Euro's a month.

The annual single customer market for Europe will approach £250M and the total worldwide market for MDUs is currently worth £2Bn. Growing threats from Internet TV (IPTV) providers even at low quality cannot be met with the status quo RF/IF satellite TV systems - the channel capacity and hardware costs are too restrictive, installation is labour intensive and power demand is excessive as well as environmentally damaging. However an optical solution will enable DBS to compete very favourably on cost and performance with IPTV for a much longer period. particularly where high definition communications are required.

Total Sales of Global Invacom Fibre MDU products since their inroduction in 2009.



Business Model

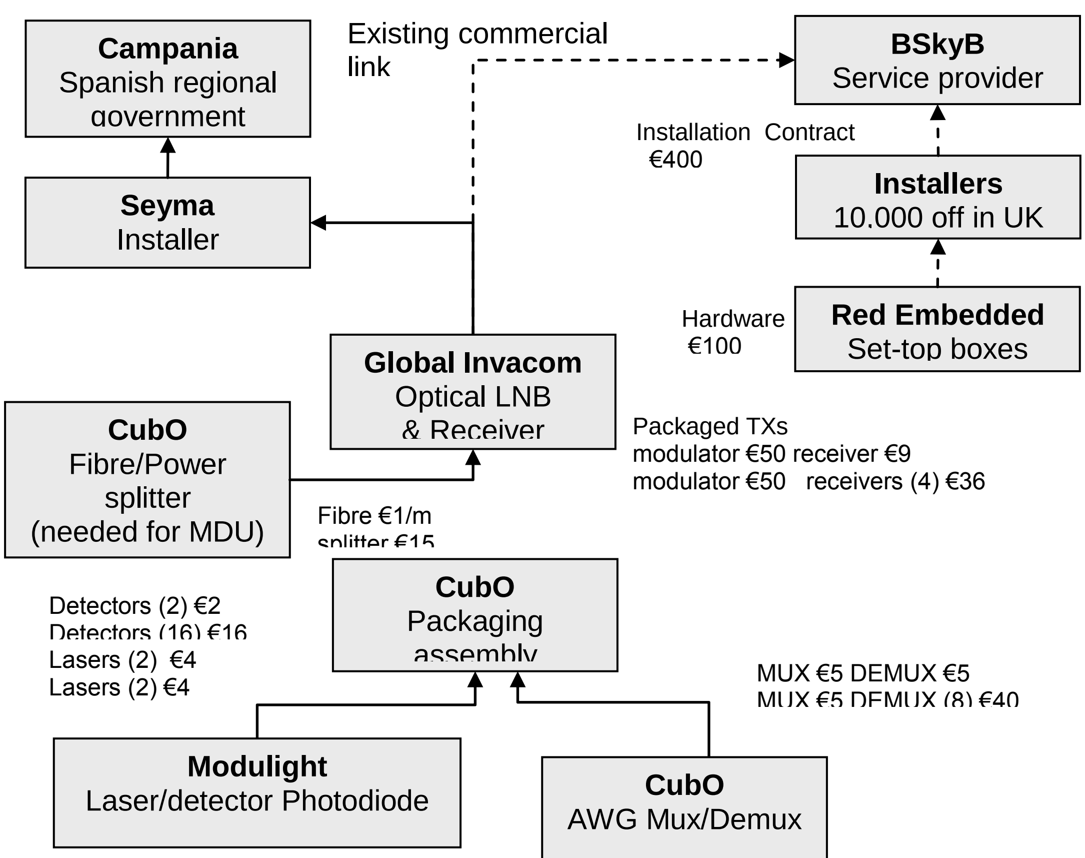
SUPPLY CHAIN

Introduction

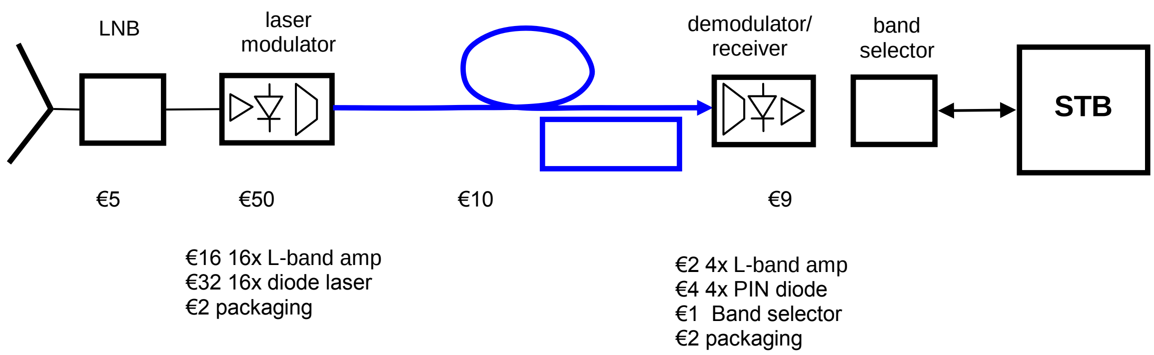
In order to present the potential revenue for each partner a typical supply chain was developed and included in the DoW. This has now been developed further in this report as multiple components, Transmit and Receive are required for a system, but for comparison purposes the original is presented below, this is clearly not going to be the only route to market for the technology but it does present the overall potential for each partner.

To further complicate comparisons against the standard approach used in the DoW is the issue that two alternative technical solutions have been developed in the project. Therefore to clearly explain the complex supply chain and allow comparisons to that presented in the DoW a multiple step approach to the Supply Chain has been developed for this Exploitation Plan.

Original Supply Chain from the DoW.



Follows below is a block diagram representation of the supply chain presented above, again from the DoW, as explained above this will be updated and expanded further in this document.



Each option for the supply chain is also compared against the supply chain costs presented in the DoW as below in table form.

Supply Chain costs as presented in original DoW

Supply Chain Costs							
Supply Chain		**Partner**	**Supply Chain Cost**	**Manufacturing Costs**	**Profit Margin**	**Profit**	**Pass-On Cost**
Distributor	3	Seyma	€ 163.98	€ 100.00	10%	€ 26.40	€ 290.38
Tier 2 Integrator	2	Red Embedded	€ 47.27	€ 50.00	20%	€ 19.45	€ 116.72
Tier 1 Integrator	1	Invacom	€ 32.81	€ 5.00	25%	€ 9.45	€ 47.27
Tier 1 Supplier	4	CubO	€ 11.25	€ 15.00	25%	€ 6.56	€ 32.81
Tier 2 Supplier	8	Modulight		€ 7.50	50%	€ 3.75	€ 11.25

Supply Chain Approach

As discussed above the supply Chain in this document has been divided into two areas to cover each of the main components developed in the project.

1) Optical Transmitter Module for LNB.
2) Optical Receiver Module for Satellite Receiver.

Also as two technical solutions have been developed for the Transmitter Module each with its own Supply Chain it has been decided to present each of these options separately.

Supply Chain Optical Transmitter Module for LNB

As covered previously two technical solution options have been developed in the project for this part of the system.

Option 1 – 4 Lasers with a 4 way optical split on each, total 16 outputs (LNB/BiQOT module).
Option 2 – 16 Lasers driven by 4 lots of 4 way RF splitters, total 16 outputs

The two options have been developed in the project as Option 1 presents potentially the lowest cost most integrated solution and will hence be the longer term ideal, but requires more cost reduction work on the Optical Splitter to be practical.

Option 2 is the higher cost solution but can be realise with current technology.

It was observed early in the project that Option 1 had major cost and technology issues that would be well beyond the timescale and cost limitations of the original project to solve. Faced with this problem it was decided to take a two path approach in order to overcome this issue.

The component that presents the most significant issue to the original project approach is the Optical Splitter from CuBo, as currently this part will cost nearer to €100 than €15.00 as presented under Option 1 here. As an example of this CuBo are currently supplying a similar 4 channel Mux part for $120 in 10-15K volumes, this part can be projected to reach the target price in time, but not within the timescales of the project. If the € 100 figure is used as presented below, it is clear to the consortia that the resultant supply Chain costs presented here would be unrealistic and impractical for the market. This cost would exceed the target set in the original DoW when subsequently combined with the Receiver Module cost.

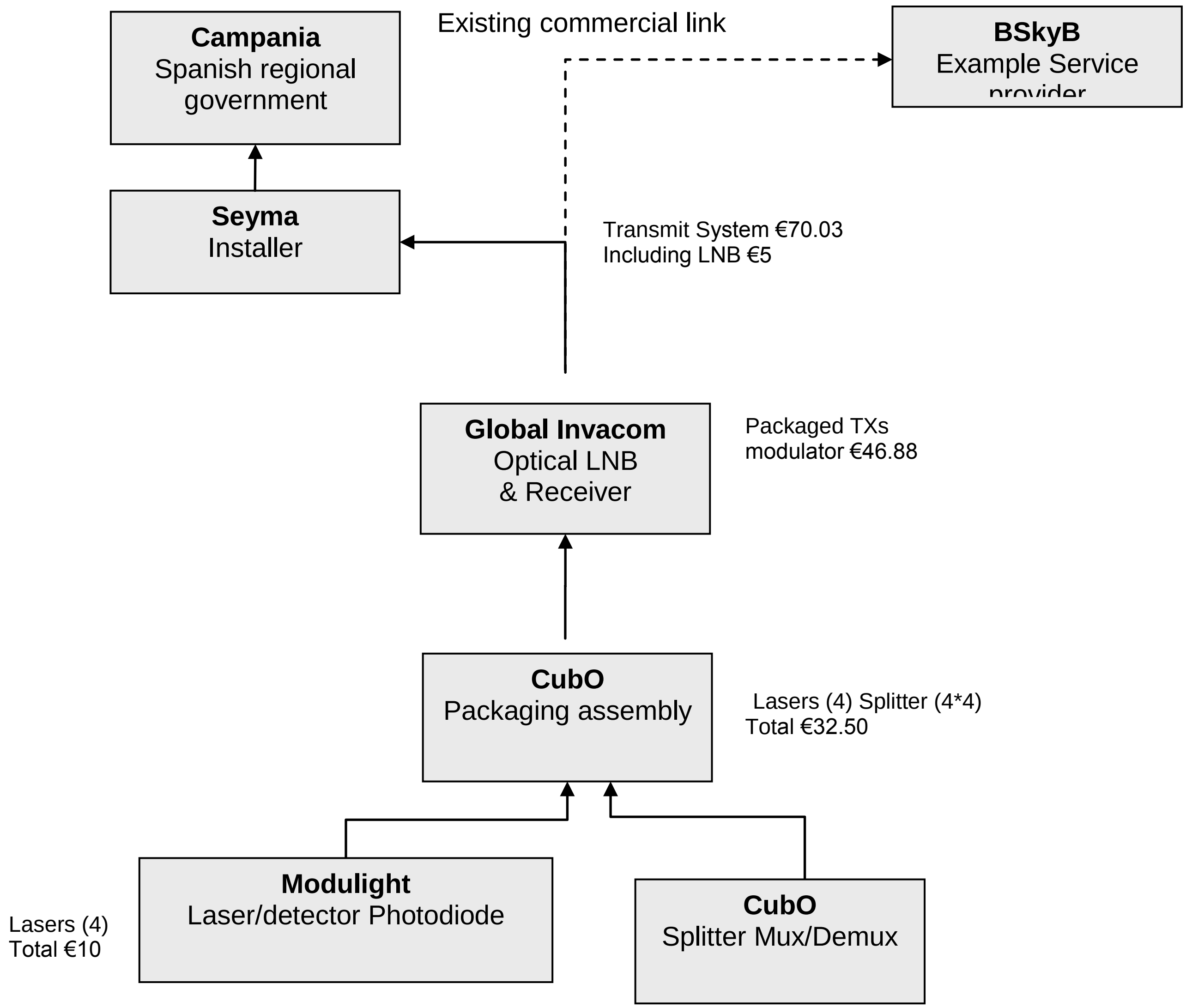
The approach therefore chosen here in all of the subsequent sections of this Exploitation Plan, is to present target figures for this Option 1 supply Chain. For this reason therefore ideal cost data for the Optical Splitter from CuBo has been to present as Option 1 at €15.00, not what can actually be achieved with the current technology.

Supply Chain with 100 Euro Optical Splitter from CuBo

Supply Chain Costs Optical Transmitter Module 4 Laser with 100 Euro CuBo Optical Splitter							
Supply Chain		**Partner**	**Supply Chain Cost**	**Manufacturing Costs**	**Profit Margin**	**Profit**	**Pass-On Cost**
Distributor	3	Seyma	€ 180.00	€ 5.00	35%	€ 64.75	€ 249.75
Tier 1 Integrator	1	Invacom	€ 137.50	€ 6.50	25%	€ 36.00	€ 180.00
Tier 1 Supplier	4	CubO	€ 10.00	€ 100.00	25%	€27.50	€137.50
Tier 2 Supplier	8	Modulight		€8.00	25%	€ 2.00	€ 10.00

Supply Chain for Optical Transmitter Module Option 1

For the Optical Splitter approach the supply chain is as follows.



Supply Chain with 15 Euro target cost for Optical Splitter from CuBo

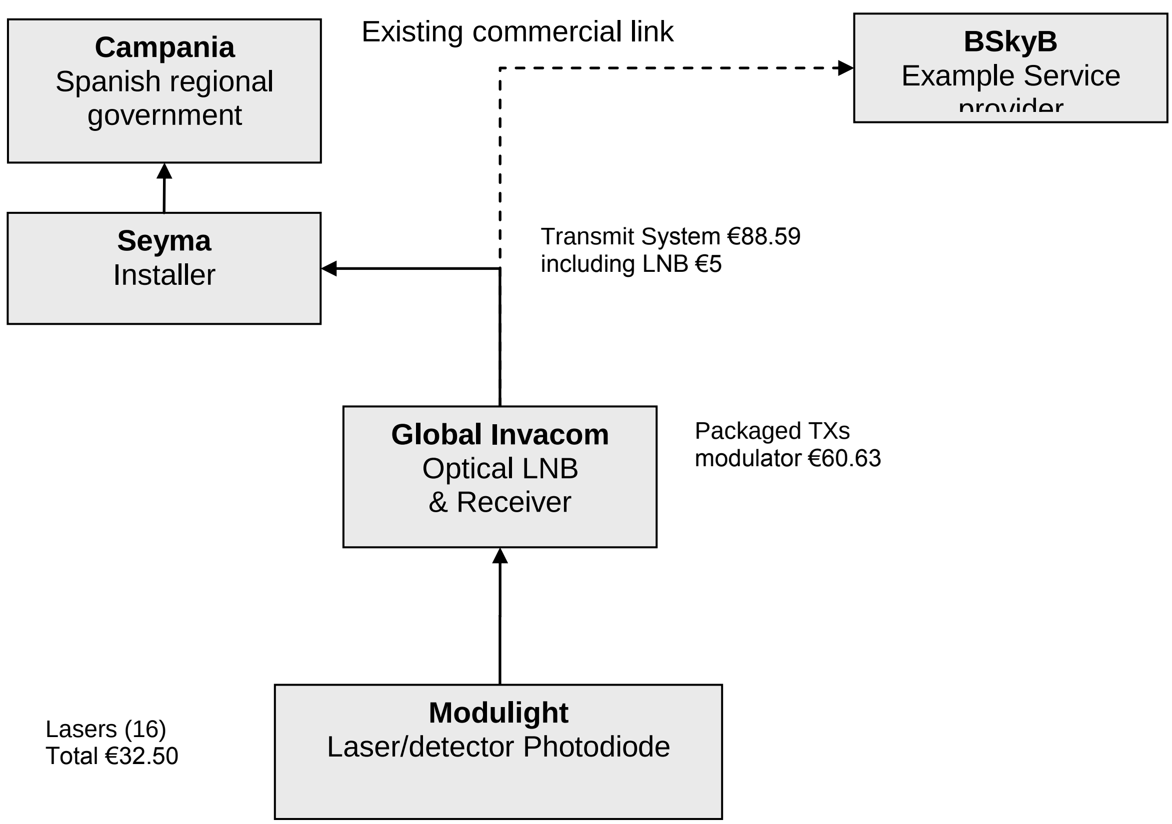
Supply Chain Costs Optical Transmitter Module 4 Laser							
Supply Chain		**Partner**	**Supply Chain Cost**	**Manufacturing Costs**	**Profit Margin**	**Profit**	**Pass-On Cost**
Distributor	3	Seyma	€ 47.19	€ 5.00	35%	€ 18.27	€ 70.45
Tier 1 Integrator	1	Invacom	€ 31.25	€ 6.50	25%	€ 9.44	€ 47.19
Tier 1 Supplier	4	CubO	€ 10.00	€ 15.00	25%	€ 6.25	€ 31.25
Tier 2 Supplier	8	Modulight		€8.00	25%	€ 2.00	€ 10.00

Supply Chain for Optical Transmitter Module Option 2

For the RF Splitter approach the supply chain is as follows.

Supply Chain Costs Optical Transmitter Module 16 Laser							
Supply Chain	**Partner**		**Supply Chain Cost**	**Manufacturing Costs**	**Profit Margin**	**Profit**	**Pass-On Cost**
Distributor	3	Seyma	€ 60.63	€ 5.00	35%	€ 22.97	€ 88.59
Tier 1 Integrator	1	Invacom	€ 32.50	€ 16.00	25%	€ 12.13	€ 60.63
Tier 2 Supplier	8	Modulight		€26.00	25%	€ 6.50	€ 32.50

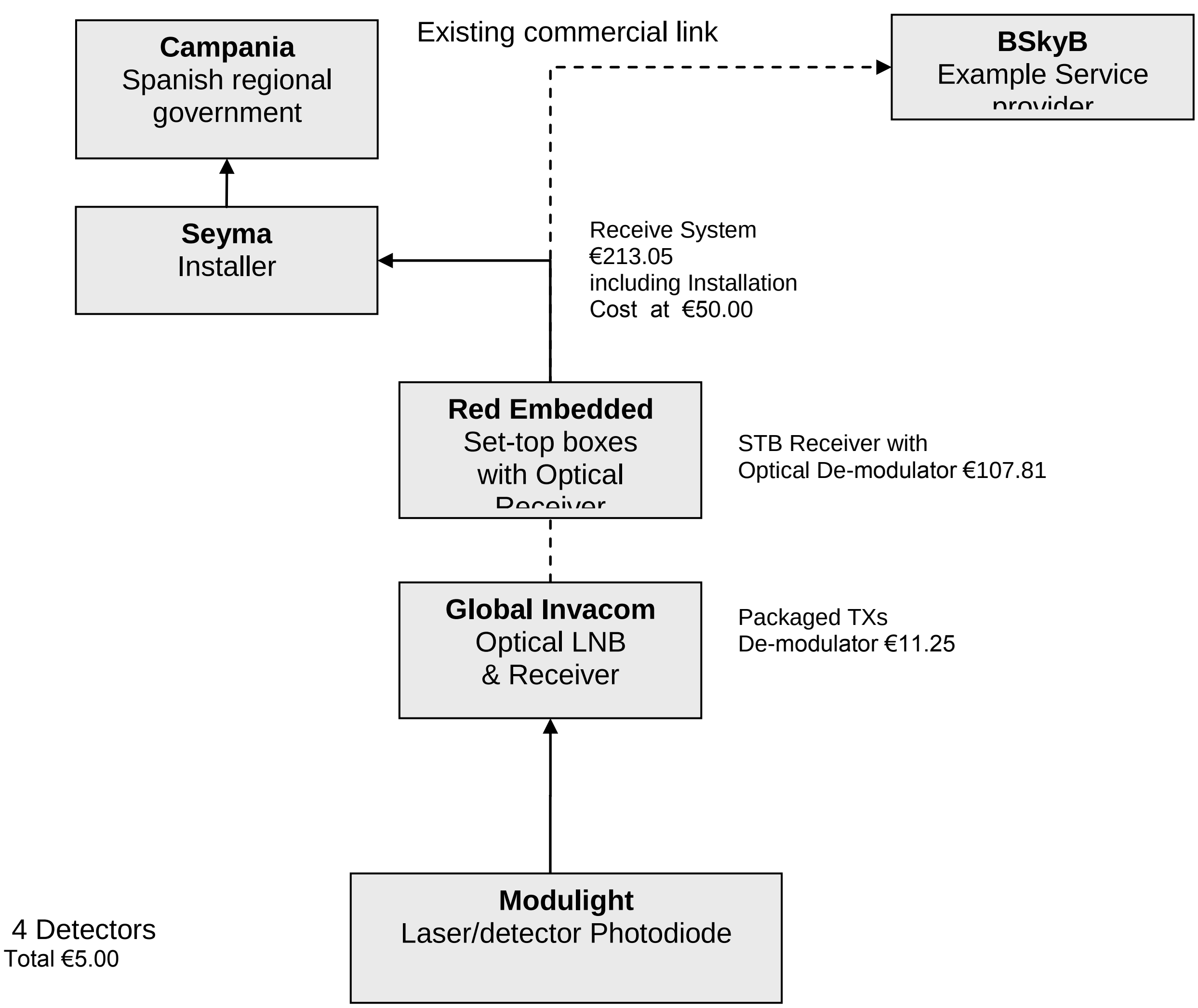
Note that CuBo is not included in this model as an Optical Splitter is not required for this solution. This does however produce a practical cost for the Transmitter Module.



Supply Chain for Optical Receiver Module

For the Receiver module only one option has been generated within the project as presented in the following supply chain.

Supply Chain Costs Optical Receiver Module 4 Detector								
Supply Chain		Partner	Supply Chain Cost	Manufacturing Costs	Profit Margin	Profit	Pass-On Cost
Distributor	3	Seyma	€ 107.81	€ 50.00	35%	€ 55.23	€ 213.05
Tier 2 Integrator	2	Red Embedded	€ 11.25	€ 75.00	25%	€ 19.45	€ 107.81
Tier 1 Integrator	1	Invacom	€ 5.00	€ 4.00	25%	€ 2.25	€ 11.25
Tier 2 Supplier	8	Modulight		€4.00	25%	€ 1.00	€ 5.00



Supply Chain Conclusions

From each of the previous supply chain sections discussed previously it is clear that a number of models could be presented for the overall supply chain. In order to make it possible to make a direct comparison with the targets set in the original DoW plan, the supply chain presented here will use the RF Splitter approach as this is currently a practical alternative using available technology.

In the table below therefore a total of each of the costs from the RF Splitter and Optical Receiver supply chain tables is presented for each partner. Subsequently these costs will then be used in the predictions of financial returns in order to present one possible model that is comparable with the original target set in the DoW.

Supply Chain Costs Optical Transmitter Module 16 Laser Optical Receiver Module 4 Detector							
Supply Chain		**Partner**	**Supply Chain Cost**	**Manufacturing Costs**	**Profit Margin**	**Profit**	**Pass-On Cost**
Distributor	3	Seyma	€ 168.44	€ 55.00	35%	€ 73.38	€ 301.64
Tier 2 Integrator	2	Red Embedded	€ 11.25	€ 75.00	25%	€ 19.45	€ 107.81
Tier 1 Integrator	1	Invacom	€ 32.50	€ 5.00	25%	€ 9.38	€ 46.88
Tier 2 Supplier	8	Modulight		€30.00	25%	€ 7.50	€ 37.50

Note that CuBo is not included in this model as an Optical Splitter is not required for this solution.

As a comparison below is the supply chain model taking the approach of using a Optical Splitter at the yet unachievable cost of € 15.00 in order to present all partner outcomes and returns. However this option will not be considered any further in this Exploiation Plan as it is currently not practical with available technology.

Supply Chain Costs Optical Transmitter Module 4 Laser Optical Receiver Module 4 Detector							
Supply Chain		**Partner**	**Supply Chain Cost**	**Manufacturing Costs**	**Profit Margin**	**Profit**	**Pass-On Cost**
Distributor	3	Seyma	€ 154.69	€ 55.00	35%	€ 78.20	€ 283.08
Tier 2 Integrator	2	Red Embedded	€ 11.25	€ 75.00	25%	€ 19.45	€ 107.81
Tier 1 Integrator	1	Invacom	€ 37.50	€ 20.00	25%	€ 14.38	€ 71.88
Tier 1 Supplier	4	CubO	€ 10.00	€ 15.00	25%	€ 7.50	€ 32.50
Tier 2 Supplier	8	Modulight		€30.00	25%	€ 7.50	€ 37.50

As can be seen from the above each of these options compares favourably with the original table set out in the DoW and presented above in the Introduction to this section. However if the € 100 figure was used for CuBo, then clearly the resultant any supply Chain costs presented would be unrealistic and impractical for the market.

PREDICTIONS OF FINANCIAL RETURNS

The lead partner Global Invacom will lead the exploitation of IP generated in this project. We are a leading provider of DBS hardware with commerical links to BSkyB and are developing our business into the optical communications sector giving acces to completely new markets. Our current Fiber range launched in 2009 and from a standing start now acheives a turnover of 10M EURO a year.

The expected direct benefit to this established business will come through access to components with improved performance and reduced cost enabling penetration into wider markets. Royalties and licence fees for manufacturing the new optical fibre link will be earned from new licences worldwide as demand inceases. As an example of this Global Invacom also currently supplies models, components and equipment on an OEM basis into other manufactures.

The commercial partners will benefit from preferential supplier positions and, after 1st year short runs, sublicensing to the other volume manufacturers. The number of systems produced over time will rise from a few thousand to the market penetration limit, anticipated to be as high as 20% (limited by competition).

The RTOs, U. Kent, ISRI and IEMN will not gain any direct commercial benefit but will drive forward their capabilities and skills through involvement in the R&D in the photonics applications sector and will be properly compensated through the allocation of funding.

We are basing our financial returns on the supply chain model shown above with partners retaining IP for the components they are involved in developing. The system chosen for an illustration of sales comprises one hybrid STB with optical input and an LNB with the 16 Laser RF Splitter module approach at the satellite dish head-end.

We illustrate below the market size, growth rate and penetration on which we are formulating for our exploitation plans for each partner. Financial returns will be based on the 16 Laser Optical Transmitter Module with the 4 Detector Receiver Module.

Year	European Market Size p.a.	Market Value p.a. Using complete installed system price	Demand p.a.	Sales Value p.a. Using complete installed system price € 301.64	Market Penetration
Yr 1	20,000,000	6,003,281,250	100,000	30,016,406	0.50%
Yr 2	20,040,000	6,015,346,875	200,000	60,032,813	0.98%
Yr 3	20,080,800	6,027,653,813	300,000	90,049,219	1.44%
Yr 4	20,122,416	6,040,206,889	400,000	120,065,625	1.88%
Yr 5	20,164,864	6,053,011,027	450,000	130,573,828	2.08%
Yr 6	20,208,162	6,066,071,247	500,000	150,082,031	2.26%
Yr 7	20,252,325	6,079,392,672	450,000	130,573,828	2.00%
Yr 8	20,297,371	6,092,980,525	300,000	90,049,219	1.31%
Yr 9	20,343,319	7,006,840,136	250,000	70,541,016	1.07%
Yr 10	20,390,185	7,020,976,939	250,000	70,541,016	1.05%
Total Yr 5			1,450,000	430,737,891	
Total Yr 10			3,200,000	960,525,000	

Market penetration (2% growth per annum)

The table is based on a 20M units overall market for Europe using the data from ASTRA market survey to the end of 2010.

The returns per partner based on the above demand numbers can now be presented in order to generate an overall ROI for the project,

Supply Chain Costs Optical Transmitter Module 16 Laser Optical Receiver Module 4 Detector									
Supply Chain		**Partner**	**5 Year Demand based on Market Size Calculations**	**Partner Pass On Cost per Unit**	**Total 5 Year Partner Turnover**	**Partner Profit per Unit**	**Total 5 Year Partner Profit**	**Investment**	**Total ROI over 5 years**
Distributor	3	Seyma	1,450,000	€ 301.64	€ 21.85M*	€ 73.38*	€ 5.32M*	€ 32K	166*
Tier 2 Integrator	2	Red Embedded	1,450,000	€ 107.81	€ 156M	€ 19.45	€ 28.2M	€ 70K	400
Tier 1 Integrator	1	Invacom	1,450,000	€ 46.88	€ 68M	€ 9.38	€ 13.6M	€ 151K	90
Tier 2 Supplier	8	Modulight	1,450,000	€ 37.50	€ 54M	€ 7.50	€ 11M	€ 65K	168

***** Note 1

Note that the returns for Seyma have been scaled down by a factor of 20 (5%) in this simple model. If not this model would have assume that all systems sold through the consortia into Europe would be installed by Seyma, in reality this is unlikely to be the case as this company only represents the products in the Spanish market, which represents a subset of <5% of the overall European market (see ASTRA market survey by country).

****** Note 2

Note that as this approach is based on the 16 Laser Optical Transmitter Module with the 4 Detector Receiver Module it excludes CuBo.

Template B1 LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS					
Type of IP Rights	**Confidential**	**Foreseen Embargo date**	**Application Reference(s)**	**Subject or Title of application**	**Applicant (s) (as on the application)**
Patents	Yes	14-07-2011 to 14-07-2013	PCT/GB2011/051323	Multiple Fibre Output Laser Product	Gary Stafford

REPORT ON SOCIETAL IMPLICATIONS

A	General Information *(completed automatically when **Grant Agreement number** is entered.*
Grant Agreement Number:	23081
Title of Project:	Optosat
Name and Title of Coordinator:	Mr Andy Dean

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	No
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	No
• Did the project involve patients?	No
• Did the project involve persons not able to give consent?	No
• Did the project involve adult healthy volunteers?	No
• Did the project involve Human genetic material?	No
• Did the project involve Human biological samples?	No
• Did the project involve Human data collection?	No
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	No
• Did the project involve Human Foetal Tissue / Cells?	No
• Did the project involve Human Embryonic Stem Cells (hESCs)?	No
• Did the project on human Embryonic Stem Cells involve cells in culture?	No
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	No
• Did the project involve tracking the location or observation of people?	No
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	No
• Were those animals transgenic small laboratory animals?	No
• Were those animals transgenic farm animals?	No
• Were those animals cloned farm animals?	No
• Were those animals non-human primates?	No
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	No

• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	No
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	2
Work package leaders	0	7
Experienced researchers (i.e. PhD holders)	6	13
PhD Students	0	0
Other	3	5

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**2**
Of which, indicate the number of men:	2

D Gender Aspects		
5. Did you carry out specific Gender Equality Actions under the project?	O √	Yes No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective ... Very effective
❑ Design and implement an equal opportunity policy	O O O O O N/A
❑ Set targets to achieve a gender balance in the workforce	O O O O O N/A
❑ Organise conferences and workshops on gender	O O O O O N/A
❑ Actions to improve work-life balance	O O √ O O
O Other:	*Partners have established equality actions in their organisation. No specific actions for this project.*

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

- O Yes- please specify
- √ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

- O Yes- please specify
- √ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- O Yes- please specify
- √ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- √ Main discipline[7]: 2.2
- O Associated discipline[7]: 1.1
- O Associated discipline[7]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	O √	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- O No
- O Yes- in determining what research should be performed
- O Yes - in implementing the research
- O Yes, in communicating /disseminating / using the results of the project

[7] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	O O	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- O No
- O Yes- in framing the research agenda
- O Yes - in implementing the research agenda
- O Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- O Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- O Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- O No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level? ○ Local / regional levels ○ National level ○ European level ○ International level	
H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	0
To how many of these is open access[8] provided?	0
How many of these are published in open access journals?	0
How many of these are published in open repositories?	0
To how many of these is open access not provided?	0
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[9]: ……………	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	1

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	0
	Registered design	0
	Other	0

17. How many spin-off companies were created / are planned as a direct result of the project?	0
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

√	Increase in employment, or	√	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:* *5*

8 Open Access is defined as free of charge access for anyone via Internet.

9 For instance: classification for security project.

Difficult to estimate / not possible to quantify	

I	**Media and Communication to the general public**

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes   √ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes   √ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
√	Brochures /posters / flyers	√	Website for the general public / internet
❑	DVD /Film /Multimedia	√	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	√	English
❑	Other language(s)		

APPENDIX A

REFERENCES

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[9] Optosat Deliverable D6.1, Modulator packaging design, June 2011
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