Satellite Broadband Revolution: How Latest Ka-Band Systems Will Change the Rules of the Industry. An Interpretation of the Technological Trajectory

Fabio Valle

Eutelsat,
70 Rue Balard, 75015 Paris, France
fvalle@eutelsat.fr

Abstract. The paper analyzes the satellite broadband systems for consumer from the perspective of technological innovation. The suggested interpretation relies upon such concepts as technological paradigm, technological trajectory and salient points. Satellite technology for broadband is a complex system on which each component (i.e. the satellite, the end-user equipment, the on-ground systems and related infrastructure) develops at different speed. Innovation in this industry concentrates recently on satellite space aircraft that seemed to be the component with the highest perceived opportunity for improvement. The industry has designed recently satellite systems with continuous dimensional increase of capacity available, suggesting that there is a technological trajectory in this area, similar to Moore's law in the computer industry. The implications for industry players, Ka-band systems, and growth of future applications are also examined.

Keywords: Technological Innovation, Value Added Services, Broadband satellite technology, Technical change, Ka-band and emerging frequency bands, Technological trajectory.

1 Introduction

After the announcement in January 2008 of the investment from ViaSat and Eutelsat in 2 high-capacity Ka-band satellites to bring satellite broadband connectivity for a joint investment of more than 700 Million US Dollars, major industry experts and analysts have noted that this investment have the potential to transform the satellite industry [1, 2]. As we will see in the following pages the technological improvement of the latest systems indicates that it represents a revolution for the satellite broadband industry.

The paper analyzes the technical trajectory of satellite broadband systems for consumer from the perspective of technological innovation. The aim is to interpret why and how the technological innovation coming from the new Ka-band system is going to modify the industry.

K. Sithamparanathan (Ed.): Psats 2009, LNICST 15, pp. 49–60, 2009.
© ICST Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering 2009

2 Inside the Innovation Black-Box

As economists became more and more aware that innovation is crucial to economic growth and increase in productivity, they increasingly have focused on the key drivers of innovation, to open the "innovation black-box" [3]. Some very useful conceptual tools have been developed to understand the paradigm behind the innovation, partners and trajectories or [4], the epistemology of engineering [5] and how these concepts can be applied to the economic systems (e.g. [6]) and companies.

This economic/technological literature helps engineers, policy makers, managers and technologists to anticipate where innovation can happen, thus to govern and promote technical progress to the extent to which this is possible.

2.1 Technological Paradigm and Technological Trajectory

In the technological/research community the focus of technologists and engineers is normally concentrated on the recognized critical problems, following the well know concept of paradigm for technological revolutions [5].

This means that when a technological paradigm is established the technological community will follow some rules to address and solve problems. For instance in the development of CPUs, it is well know the Moore's law that says that the capacity of the CPU will double every 18 months. This "rule" is both a target for the industry and a strong orientation to solve the relevant problem. In other words all the technologists of the industry are focused to address the improvement of CPU and not other possible dimension of improvements. This paradigm, as explained by Dosi [4], drives innovation and allows predicting the direction of innovation[1].

Using a metaphor, paradigms are "the glasses" of the technological community and tell them what are the relevant problems to address. Understanding "the glasses" of each technological community allows to read the future and anticipate industry evolution.

2.2 Externalities

The diffusion of innovation is enhanced by the availability of externalities.

In economics terms, an externality is defined as an impact on any party that is not directly involved in an economic decision. An externality occurs when an economic activity causes external costs or external benefits to third party stakeholders who did not directly affect the economic transaction. We can have positive or negative externalities. For instance the creation of technical knowledge in a certain field is a positive externality because it facilitates the further development of additional technical knowledge or innovation.

For the technical progress we consider 2 useful examples.

1. Network externalities. An individual buying a product that is interconnected in a network (e.g. a video cellular phone) will increase the usefulness of such phones to

[1] Of course the technological paradigm can forecast the direction of the innovation, but not the specific innovation that will allow meeting the goal set by the paradigm.

other people who have a video cellular phone. When each new user of a product increases the value of the same product owned by others, the phenomenon is called a network externality or a network effect.

2. Spillover effects for technical knowledge. Knowledge spillover of inventions and technical information - once an invention (or most other forms of practical information) is discovered or made more easily accessible, others benefit by exploiting the invention or information. For instance the development of knowledge on the best wing profiles according to speed helped the aviation industry to rely on those profiles for aircraft design.

In particular on the aspect of technical knowledge technological change literature has widely recognized that the most important knowledge required for innovation is the tacit knowledge. Tacit knowledge is the type of information and competence that is specific to a certain domain of application (e.g. Ka-multi spot satellite design not general satellite design) and is not easy to transfer from one field to another. Tacit knowledge is seen in contrast to the scientific knowledge that can be applied to many fields and it is more general in its domain of application. The availability of tacit knowledge in a specific industry, typically coming from experience, is a positive externality, because it is a catalyst for innovation.

Positive externalities typically reinforce/accelerate the existing technological trajectory.

3 Satellite Broadband for Consumer: An Interpretation

The broadband satellite for consumer is an illustrative example for the analysis of technological progress because it permits to capture all these forces at work. The satellite industry in fact is the high-technology field that is behind some of the most important innovations of our times, such as satellite television, navigation system, GPS.

The most recent development is the satellite broadband system for consumers that have been developed widely in the US. In 2008 in the US there were almost a million consumers that are using satellite broadband as their primary internet connection [9].

To bring satellite broadband to consumer a certain number of technological components are necessary: (a) the satellite capacity from a geostationary satellite, (b) the end user equipment (antenna and modem), (c) the on-ground equipment (e.g. hubs), (d) other infrastructure (e.g. network, fiber connectivity). Each of these components is developed by a different industry and all together they represent a technological system. The innovation of each component is independent and managed by different actors. For instance satellite is developed by the space industry, while the antenna and the modem are developed by specialized manufactures of electronics/mechanical equipment.

3.1 Recognized Reverse-Salient Points by the Satellite Industry

As we have seen in the previous chapters, in the technological/research community the focus of technologists and engineers is normally concentrated on the recognized

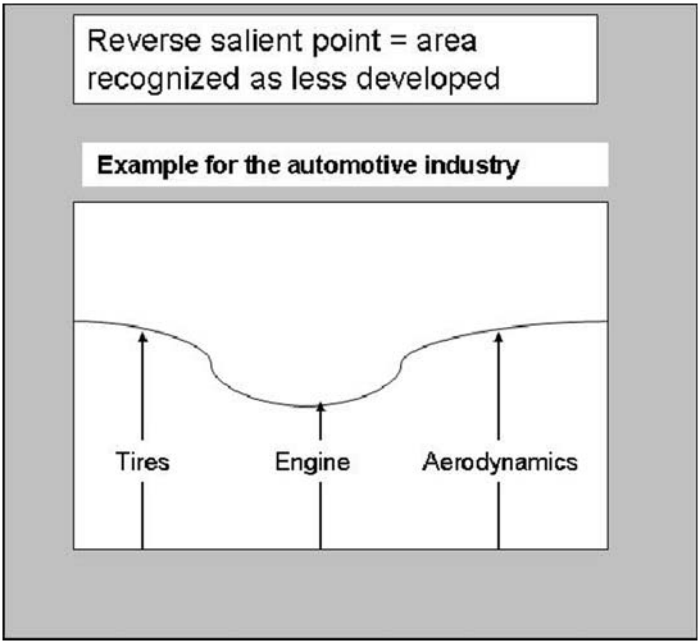

Fig. 1. Example of reverse-salient point for a complex system

critical problems, following the well know concept of paradigm for technological revolutions [5].

New satellite systems for broadband (i.e. the satellite, the end user equipment, the on-ground systems and related infrastructure) are complex system on which each component develops at different speed.

In complex technological systems with several components the effort is concentrated in the area that is perceived to lead to highest improvement. This concept is called reverse-salient from military strategy applied to innovation [6].

In simple terms this means as in the disposition of the military forces the reverse salient is the area less developed, where our army is less advanced (see example above).

During the previous phase the industry concentrated mainly on the reduction of the end-user equipment. The VSAT were initially very expensive around 10.000 US dollars per unit with big antennas. Then, they decreased to 2.000 US dollars thanks to the use of star network architecture with big antennas and the intelligence to share the capacity in the hubs. More recently in 2003 the prices had another decrease below 1.000 US dollars with DVB RCS like systems. The use of standards (such as DOCSIS for ViaSat) and the re-engineering of terminal allowed another dramatic reduction to below 500 dollars.

3.2 The New Reverse Salient: The Satellite Capacity

With price reduction, the industry moved the recognized reversed-salient point. The newly recognized critical problem to address was satellite capacity.

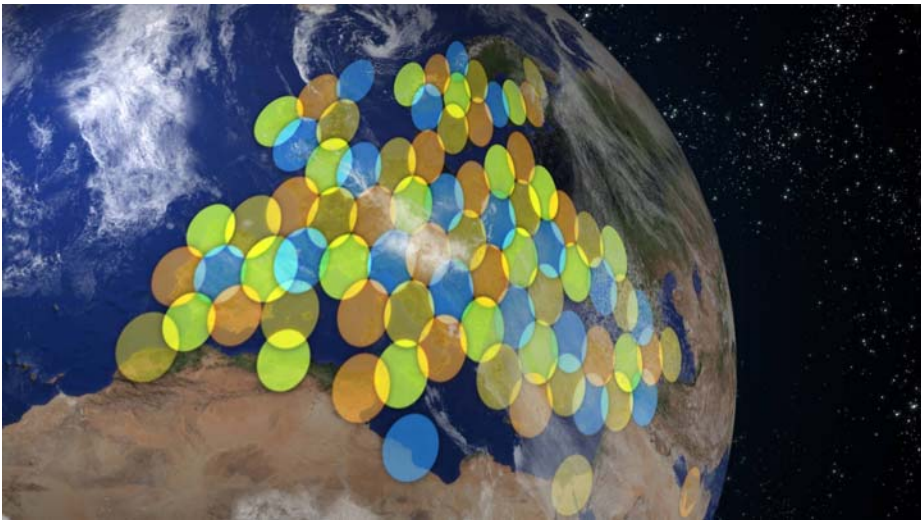

Fig. 2. Eutelsat KA-SAT coverage shows the frequency reuse (different colors for different frequencies)

The industry addressed this problem with spot beams and frequency reuse among the spots with Ka-band frequency with an extraordinary efficacy. The newly designed satellites announced worldwide are those ordered by Eutelsat and ViaSat in Ka-band.

They have made major improvement compared to previous generation thanks to frequency reuse.

Each satellite has specific radio spectrum assigned by regulatory authorities. Each satellite can operate only within that range. The spot beam design of KA-SAT (see figure below) allows a very high “reuse” of the same frequency assignment multiple times on a satellite where each beam of the same colour (i.e. blue, yellow, tan or orange in the below example) broadcasts on the same frequency. Beams of the same colour never touch each other, therefore do not cause interference, and this design allows for much, much greater throughput capacity on the satellite.

The increase of the capacity is supported in two ways by the frequency reuse. On one hand there is an increase of capacity for the reuse of frequency as said before, on the other hand, the reuse allows smaller spots and therefore concentration of power, thus better uplink and downlink performances in the said spots.

Given the complexity of the frequency reuse, the on-ground infrastructure should follow the satellite design to match antennas with spots of the right color, therefore an integrated infrastructural project (satellite + on ground) is needed.

3.3 Dramatic Improve in Performances

The increase in the capacity is dramatic compared to standard Ku-based large beam satellites and to typical Ka-band satellites. We talk about an increase of 18-25 times of available capacity.

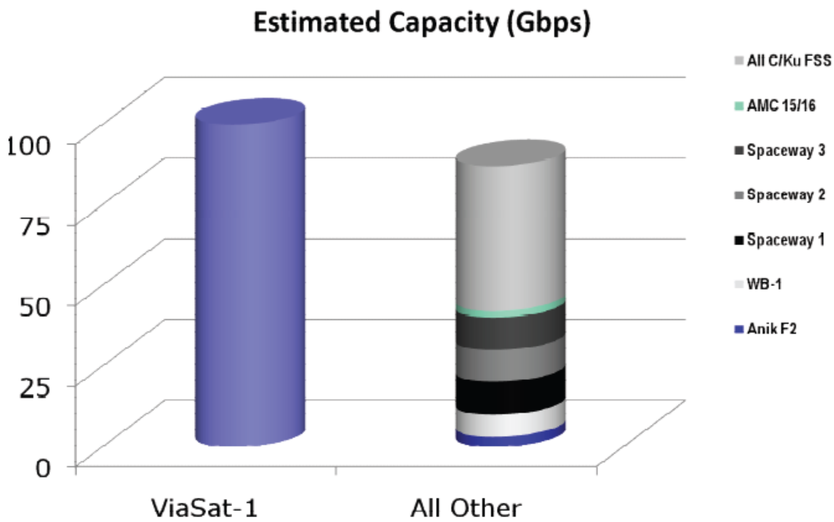

Fig. 3. Analysis of satellite capacity of satellite systems covering the United States

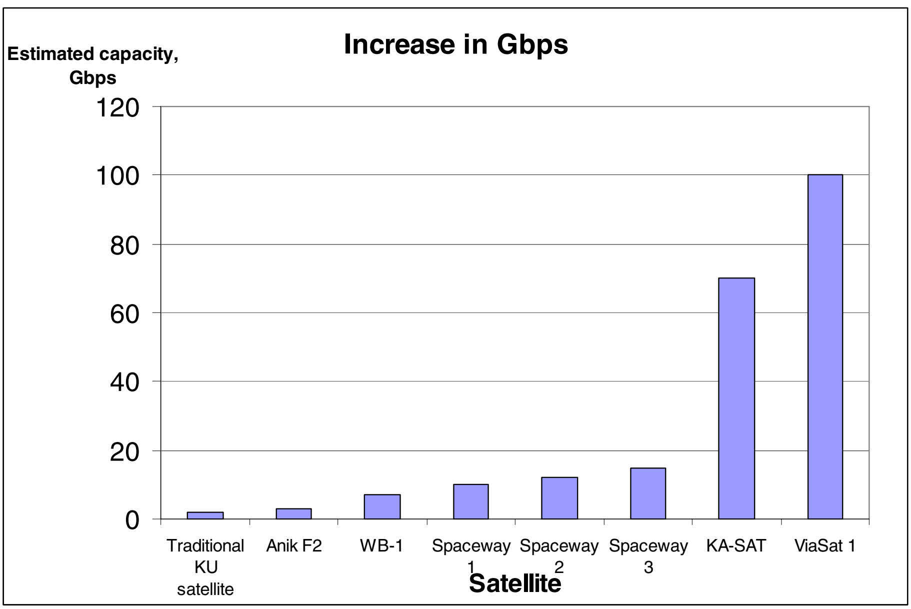

Fig. 4. A dramatic increase of capacity from a satellite of the new generation compared to previous ones (source: industry estimations)

For instance ViaSat-1 satellite in 2011 will have more capacity than the combined C-band, Ku-band and Ka-band satellite now existing in the US (see next chart). From the previous paragraph, we have learned that the main drivers of this improvement are: a) smaller spots that leads on one hand to the increase reuse of frequency and on the other to better coverage (both in uplink and in downlink), c) integrated design of on-ground infrastructure and satellite system.

A deeper analysis of the date of design of the satellite system and the capacity available in Giga-bit per second lead us to believe that a technological trajectory exists, similar to law's Moore for CPU capacity in transistors.

Other operators planning new satellite in the US for broadband use such as Hughes and other companies in Europe and in other Regions seem to go on the same direction, thus confirming the validity of the innovation and the existence of this paradigm.

3.4 The New Paradigm: What Are the New Rules of the Game

If we try to analyze the change from the paradigm perspective, we can better understand this shift in the industry.

The initial paradigm was to make some entry-level service with limited capacity in Ku, we call it *market entry*. The new paradigm is to create a *bit factory*. In the *market entry* the goal was to pursue the most profitable part of the market: business to business market and specialized applications. In the *bit factory* approach the goal is to serve also the consumer market that requires typically more capacity at lower price, but of course they provide a much higher volume of revenues.

We would like to stress especially three new rules of the new paradigm.

1. **Higher chip to enter into this business.** While in the previous paradigm a generic satellite capacity could be used, the new one requires a specifically built satellite or at least a dedicated part of the payload. Given the cost of investing in satellite infrastructure, this raise the stakes for players that want be in the game.
2. **New generation Ka-band satellites need an integrated on-ground infrastructure.** The vision here is to have a global infrastructure both satellite and ground. As we said before given the complexity of the frequency reuse, the on-ground infrastructure should follow the satellite design, therefore an integrated infrastructure is needed.
3. **Higher number of users managed.** The move to consumer and with much more capacity available implies that each operator will have to address a much bigger number of subscribers. This implies the need for proven systems that can manage all these users. This means a concentration of existing hardware vendors.
4. **Closer ties between hardware manufactures and satellite operators.** The importance of ground segment from the satellite development to the operation will drive to closer links within the industry between hardware manufactures and satellite operators.

Table 1. Difference between the 2 paradigms and key dimensions

Paradigm key dimensions	Market entry approach	Bit factory approach
Definition of the technological system	Hub, end-user equipment	Hub, end-user equipment, satellite system
Technological objective	Low terminal price and efficiency in use of capacity	Increase of an order of magnitude the capacity transmitted per unit of cost
Engineering of the solution	Engineering of hub and terminal solution with generic satellite capacity	Integrated engineering of satellite, ground segment and end user equipment
Role of hardware vendor	Off the shelf solution for generic satellite capacity	Customized engineering based on satellite capacity
Importance of hardware manufacturer in satellite design	Not relevant	Relevant throughout the product cycle.
Barrier to entry	Low (few million USD) for antenna and hub equipment	High (require a specific satellite investment)
Risk	Low (investment just on ground)	High (satellite design is not changeable)
Potential clients	Enterprise market, institutions	Consumer market, Enterprise market, institutions
Average number subscriber managed per hub	4-6.000 per hub	Up to 200.000 per hub

3.5 Why Ka-Band

Several reasons explain the choice to go to manufacture a dedicated Ka-band satellite for broadband services [12]:

1. **More spectrum available and better interference environment.** There is more exclusive spectrum available at Ka-band. The Exclusive Band in Ku-band is limited to 250 MHz on the uplink and spans from 14.25 GHz to 14.50 GHz while the available spectrum at Ka-band is double that spectrum, i.e. 500 MHz on both uplink (29.5 – 30GHz) and downlink (19.7 – 20.2GHz). The Exclusive Band in

Ka-band has a better interference environment and its use is limited to small terminals.

2. **Smaller embarked satellite antennas.** Ka-band allows to have smaller antennas on the satellite to cover a spot of a set dimension compared to Ku-band. We assume that the satellite antenna aperture is limited by the satellite configuration and the launch vehicle fairing and that the terminal aperture is defined by the service.

3. **Suitable service availability.** It can be shown that in Europe, for an availability of up to 99.7%, it is still more suitable to work in Ka-band with respect to a Ku-band system.

4. **Ka-band support smaller cells and higher frequency reuse and coverage.** Ka-band is approximately two times higher in frequency than Ku-band. Higher frequency also means that for a given satellite antenna aperture the beam is smaller, allowing smaller cells. Smaller cells imply a better individual coverage.
   On the Forward Link (gateway-to-terminals) this permits to ensure that the satellite power is used efficiently on a more limited area with the required EIRP (effective isotropic radiated power) to get closer to the given user.
   On the Return Link (terminals-to-gateway), this improves the G/T (gain-over-temperature) of the satellite ensuring that for a given bit rate smaller resources are required at the terminals in terms of RF (radio frequency) power required from the HPA (high power amplifier) and antenna aperture. All this contributes towards smaller terminals.

5. **Does not use the commercially valuable DTH frequency.** Using a traditional Ku-band satellite at a premium orbital slot dedicated to DTH services would and reduce capacity for DTH channels.

4 Foreseen Industry Evolution

The future evolution of course depends heavily on the commercial success and profitability of the newly launched satellite broadband projects and on the market opportunity for broadband applications. The well-documented and recognized digital divide in all the countries shows the need for broadband connectivity both in the US and in Europe and seems to fully justify the investment made by the industry [10, 11].

Most recent research study indicates that users will have an increasingly appetite for bandwidth pushing further the logic of the *bit factory* approach versus the logic of *market entry* approach.

In this context old players will have to decide whether they should compete with the old weapons or to invest in the new generation satellite systems completely dedicated to broadband.

The quantum leap of the new paradigm is on one hand too important and on the other too relevant for the service quality not to consider it. Firstly the improvement is too important dimensionally to be neglected (see chart below). Secondly the cost of capacity is so crucial in the service delivery chain that cannot be ignored. We are not talking here about an ancillary feature, but about the single most important reason why customer buy a broadband service, the bandwidth.

Beaming Down

Cost of building satellite Internet service, per bit

Company	Cost
ViaSat*	**$3.50**
Eutelsat*	**5.00**
WildBlue	40.00
SpaceWay*	40.00
Traditional fixed-satellite systems	225.00

*Proposed

Sources: ViaSat and industry estimates

Fig. 5. Cost per Kbps with the new generation of satellites [1]

4.1 Future Ka-Band Applications

The dramatic decrease of industrial cost of satellite capacity might fuel an increase number of applications based on Ka-band.

On the broadband business besides typical broadband access the additional applications are: VOIP, IPTV, and other Ku/Ka DTH video service. Players are moving towards a stronger push for triple play service where the DTH in Ku can be seen an additional video service on top of IPTV. This is why Eutelsat in Europe is talking about 3+1 services (triple play on Ka and video on Ku).

On broadcasting area the main applications are: personal broadcasting, regional television on satellite, micro-broadcasting, and also satellite news gathering to support smaller players. All these application will benefit from the lower cost of capacity and the regional coverage of spot beams.

On the data business key applications are: business to business applications, high-speed data casting (with peak speed above 100 Mbps), back-up for emergencies. These applications are supported by the much higher capability of the satellite and the new technology available.

With the success of these applications the *bit-factory approach* might be pushed further. Again the application development is another of the key positive externality that has a strong network effect and can lead to exponential adoption rates. All these elements create the demand for Ka-band and will push for even bigger capacity satellites.

4.2 Ka-Band: A Bright Future Ahead

Externalities will play an important role in making stronger the future of Ka-Band.

The important investment already done by WildBlue, ViaSat and Eutelsat in the most advanced markets for broadband can have positive spillover effects on technical knowledge both the competence required for the mass production of antennas, hardware, and other RF components (both in the hubs and in the end-user equipment) and on the industry competence to produce satellite. Of these competences some of this is strictly related to Ka-band (like the RF part and the satellite skills on Ka), the other is somehow transferable to Ku. Only the first one will play a major role in supporting the choice of Ka-band.

Moreover new applications like regional television that have strong network effects can drive adoption of Ka-band end-user equipment in larger areas of the population in Europe as in happens in the US.

Both effects will reinforce the choice of Ka-band in the future for these type of systems in Western Europe and North America.

5 Conclusions

In the interpretation of the technological evolution of the satellite broadband industry, this paper shows that the reverse-salient points moved from cost of the end user terminal to the satellite capacity.

The paradigm has moved from a *market entry* approach to a *bit factory* approach. This implies a) a closer activity between hardware manufactures and satellite operators in the satellite broadband market; b) a higher concentration of the industry both on the hardware vendors and on the service operators at least for Ka-band segment; c) more integrated design of satellite and on ground segment.

We foresee that there is a technological trajectory in this area, similar to Moore's law in the computer industry driving down the cost of capacity.

We argue that there will be a bigger role for Ka-band systems in the future thanks to the positive externalities that the investment of 3 major companies have done so far and will do in this market. Ka-band for satellite broadband seems here to stay.

References

1. Pasztor, A.: Firms Team Up to Offer Internet Via Satellite in Trans-Atlantic Push. Wall Street Journal, A16 (January 8, 2008)
2. NSR, Crystal Balling the Transformed World of Ka-Band Broadband Services, Broadband satellite markets, 6th edn. (2008)
3. Rosenberg, N.: Inside the Black Box: Technology and Economics. Cambridge University Press, Cambridge (1982)
4. Dosi, G.: Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change, Research Policy, Elsevier 11(3), 147–162 (1982)
5. Vincenti, W.G.: What Engineers Know and how They Know it: Analytical Studies from Aeronautical History. Johns Hopkins University Press, Baltimore (1990)
6. Souitaris, V.: Technological trajectories as moderators of firm-level determinants of innovation. Research Policy 31(6), 877–898 (2002)

7. Kuhn, T.S.: The Structure of Scientific Revolutions. University of Chicago, Chicago (1970)
8. Hughes, T.P.: Reverse salients and critical problems: the dynamics of technological change. In: Dosi, G., Giannetti, R., Toninelli, P.A. (eds.) Technology and enterprise in a historical perspective, pp. 97–118. Clarendon Press, Oxford (1987)
9. NSR, Broadband satellite markets, 6th edn., pp. 1–6 (2008)
10. iDate, Satellite Broadband in Europe & North Africa (April 2008)
11. United States Government Accountability Office, GAO, Report to Congressional Commitees, Telecommunications, Broadband Deployment (May 2006)
12. Benoit, G., Fenech, H., Pezzana, S.: Triple play over satellite, Ka-band making the difference. In: International Conference on Personal Satellite Services, PSATS 2009, Draft version (March 2009)