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NLR-TP-98326

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This report is based on a presentation to be held during the 1998 European Microwave week, 5-9 October.

Division:	Space
Issued:	July 1998
Classification of title:	Unclassified

Contents

(14 pages in total)

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ABSTRACT

The lack of direct access to satellite data is a major global restriction on resource management needs in developing countries. The removal of this obstacle lies in direct readout satellite transmissions and low cost, reception systems for local area data acquisition and processing. This paper outlines relevant developments and trends in earth observation with respect to the reception and processing of high resolution[1] satellite SAR data for local, near-real-time applications. It will focus on the advantages of low cost local reception to stimulate the wider uptake of earth observation data in many environmental applications. This paper will describe in particular a low cost development called RAPIDS (Real-time Acquisition and Processing – Integrated Data System).

INTRODUCTION

There is a clear environmental and commercial need to stimulate high resolution data markets and product uptake in both developed and developing world. An EU funded study (EOS *et al*, 1996) on the constraints and opportunities of Earth Observation in developing countries identified the lack of more direct access to satellite data as a major global restriction on resource management needs in these countries.

[1] Here high resolution means 5 to 30 m resolution

Reduced ground station operational costs, lower data (capital and running) costs, together with an improved, timely service to customers, especially in developing countries, will remove this obstacle and will be highly advantageous for applications development and market growth. So much so, that access to remote sensing data will become increasingly open to many potential users that would otherwise not be aware of, or inclined to utilise earth observation products and information.

Remote sensing satellite operators and data providers currently rely on a system of large, regional ground stations for operational data acquisition and dissemination. However, this presents significant obstacles to meeting the needs for inexpensive and timely data of a very large number of potential EO users. Most of the investment in Earth observation (EO) goes into the space segment rather than the ground segment. What the user sees of EO is the data distribution (ground segment) side. Growth in demand, the variety of satellite data available and increases in the number of applications mean that greater flexibility in data access is therefore necessary to improve the supply side. This requires increased consideration of direct broadcast and a lower level of control of data distribution. (Harris, 1997).

PROBLEMS IN THE ACCESS TO DATA

In many previous studies problems have been observed in the access to data, especially but not limited to developing countries (Westinga *et al*, 1993; EOS *et al*, 1996; SSC, 1993).
Access to data, especially when data are crossing borders, is hindered by technical factors, by economic factors and by political factors.
Technical factors relate to:

- Cloud problems [Optical satellites cannot see through the clouds]
- Interpretation of SAR data is perceived as being difficult
- Training and education are lacking

Economic factors relate to:

- Prices of data are too high
- Ground station access fees are too high
- Copyright

Political factors relate to:

- Security issues
- National prestige
- Autonomy

Of these factors, the political factors cause the most problems, particularly in developing countries. Especially in the case of regional operating ground stations, it is virtually impossible to get data from that station if you are not a user in the same country. The CRISP ground station in Singapore is perhaps the only positive example in this respect.

TRENDS AND DEVELOPMENTS IN EARTH OBSERVATION DATA RECEPTION

Under the present political pressure to ensure the use of space for the benefit of mankind and thus to guarantee access to earth observation data for everyone, several trends in data reception are observed. These trends are summarised in table 2.

REGIONAL OR LOCAL GROUND STATIONS

Regional ground stations used to be very attractive from the satellite operator's point of view, because a lot of potential users could be served through minimal investments. The technology of large ground stations was, at that time, very expensive and thus sharing a ground station with many users was to be profitable. However, the technology of ground stations became less and less expensive and it became clear that the operation of large regional ground stations proved difficult (in terms of access to data, reported sales etc). At the same time, the users of earth observation data became more and more aware of the opportunities that earth observation data can offer for their operational applications i.e.

delivering environmental information based on Earth Observation techniques is of importance to those operational users. These users rely on this kind of information in order to manage the environment. Information on the state of the environment has therefore certain economic value to these users since it provides them with up-to-date information. As such the market principles in which **industrial suppliers** provide products and services required by the user must be applied. However, as in many market examples the requirements for certain products and services are stimulated. As such there will always be a transition from technology push to market pull. The trend that is observed is clearly following the market pull approach by paying more and more attention to fulfilling user requirements and real operational user needs. One such important need is the continuity in data access: the user needs to be sure he can get hold of the data whenever he wants to. That can only be achieved when the user can control his own data access, i.e. by operating a ground station locally .

ONE-OFF OR SUSTAINED DATA DELIVERY

Earth Observation satellites have often been regarded as scientific data collectors for a given research and development subject. As such continuous delivery of mass data and access to data were not high on the priority list. However, in serving operational needs continuous access to data and continuous delivery of data and information becomes pertinent. A researcher requires discontinuous small amounts of data, whereas an operational user requires continuous amounts of data. An operational user has to rely on the data (“it needs to be there”), with the risk that sometimes the data does not contain the information required in the absence of the relevant features. A researcher will treat his data as being high valued data, whereas an operational user will treat his data as a newspaper (“ if I don’t read it today, it’ll be in the papers tomorrow as well”. Control over the access to data is necessary as a user will be able to decide for himself if he wants today’s data or not.

HIGH COSTS OR LOW COSTS

Businesses, who’s primary objective is to make a profit, depend on the economic factors, explained above. Costs can be subdivided into two major categories: capital costs and running costs. Capital costs, i.e. the price of a single regional ground station, has always been in the tens-of-MUS$ region.

Until recently it was not possible to buy a ground station under 4 or 5 MUS$. Now, the prices of local ground stations are even below 0.6 MUS$. This price is very attractive to operational users.

Regional ground stations have to employ a lot of staff to keep the station in operation. E.g. the CRISP Singapore station employs a staff of 12 persons, 24 hours a day. Local ground stations can do with less staff. The NLR experience, having operated a RAPIDS station for almost a year now, shows that 1 person for three hours a day can do all the required activities to plan, capture and process all satellite data for that day.
The access fees, fees to be paid to the satellite operators are still perceived to be very high. But the actual unit price calculated on the basis of these access fees is a factor 2 to 3 cheaper than the list price, as presented by the commercial distributors.

RESEARCH VERSUS OPERATIONAL USE

The trend in earth observation is to go from research and development use to operational use. Under political pressure to justify the large investments in space hardware and the perceived lack of the use of the data, the stimulation of operational oriented programmes has started. So far, this hasn’t led to any new insights but users of earth observation data are beginning to look into operational applications more and more. Local ground stations could be the trigger for that, because it is now realised what the potential, as long as you can control and rely on the data capture, is of a continuous stream of data.

LONG THROUGHPUT TIME VERSUS NEAR REAL TIME

The throughput time for data originating at regional ground stations is too long. Sometimes it is reported to last over 6 months before the data arrives at the site of the user. Again, controlling the access to data, by using your own local ground station, enables the user also to speed up the processing of the data.

GROUNDSTATIONS ALTERNATIVES

Basically there are a limited number of providers of ground stations for the reception of high resolution satellite data.

Company	Name of station	Antenna diameter	Approx. Coverage (diameter)	Price[2]
Datron Systems Inc, US	Open 2000 Earth Station	3.6 – 13.0 m	1500-3000 km	Not available
MDA, Canada	FastTracs	4.3 – 5.0 m	2000 – 2500 km	4-5 MUS$
Vexcel, US	VxDCS	4.3 m	2000 km	2 MUS $
RAPIDS, UK /The Netherlands	RAPIDS	2.7 m	1000 km	0.5 MUS$
IOSAT, Canada	Sentry	5.4 m	2500km	Not available

A LOW COST LOCAL EXAMPLE: RAPIDS

Research developments funded by the UK Government Department For International Development (DFID) and British National Space Centre (BNSC) have produced RAPIDS - a PC based receiver system for ERS, SPOT and JERS data. In parallel, The Netherlands Remote Sensing Board (BCRS), the Netherlands Agency for Aerospace Programmes (NIVR) and NLR are funding the development of the data processing system and a number of field trials in Europe and overseas (Downey *et al*, 1997).

RAPIDS DESIGN REQUIREMENTS

The Real-time Acquisition and Processing - Integrated Data System (RAPIDS) is a PC-based X-band receiver designed to provide local users with rapid access to earth observation data at least cost.

The design philosophy of the RAPIDS PC-based transportable ground station is to meet national and/or local needs for timely environmental data. In most countries, a large number of resource managers, planners and decision makers would benefit from timely information on their environment, if it were available promptly (on demand), reliably and as inexpensively as possible Williams and Rosenberg 1993). For these local areas/users the demands are less than for horizon-to-horizon systems. Thus the resulting ground segment can be inexpensive, easy to transport, install and maintain.

[2] Prices are based on initial cost estimations given by the manufacturers

The principal design requirement is for a system to handle capture for local areas when the satellite is within ± 45° of the overhead position. The system has to maximise control during these passes where the rate of change in satellite position is highest. The ± 45° cone of acquisition enables capture of small unit volumes of data of local interest. The system also has to be robust enough to minimise the effect of wind forces during tracking, and to be simple to maintain and operate. Standard PCs were selected as the platforms for management, tracking, capturing and processing of data. This is because of their increasing performance/cost advantage and their widespread availability and use (compared to UNIX workstations) in developing countries. This makes for easier local maintenance and cost-effective integration with existing capacity

BURS designed and now manufacture the system. NRI and NLR provide processing software, applications development, project implementation and technical support.

RAPIDS SATELLITE TRACKING AND DATA RECEPTION

Many high resolution satellites include a beacon (e.g. ERS) or data signal operating on a 2.2 GHertz signal, the satellite pointed tracking is done using this frequency. All the current high resolution satellites transmit data on the 8 GHertz band and these data streams are collected separately so as not to mix the tracking function with data collection issues.

The current set-up for receiving consists of a dish antenna of 2.7 metres that can be tilted over a range of +60º to -30º in two perpendicular directions. This range is enough to capture data within a circular area of approximately 1000 km diameter, depending on the site. A set of four patch aerials each with its own low noise amplifier for the 2.2 GHz tracking system is mounted at the dish centre. The 8 GHz data reception LNA is positioned in the same focal plan as the patch aerials at the centre of the dish.

The antenna dish is moved by a hydraulic configuration. A hydraulic power unit with oil reservoir pumps, motors, and valves controlling the drive rams is used to move the aerial. Position monitors are linked to the power supply for safety cut out, “safe park” mode and alarms. The receiver system is thus capable of tracking on S-band beacon signals and capturing X-band data signals from satellites over 90 arc-degrees using a 2.7 metre antenna. Capability currently includes ERS, SPOT and JERS. Potentially, other satellites (e.g. IRS, Landsat, EOS et al) could be added to the capability.

Data rates that can be captured vary from 6 Mbits sec^{-1} to 150 Mbits sec^{-1}. For example, the data rate of ERS is 105 Mbits sec^{-1}. These data rates limit the use of standard computers. Nonetheless, due to improvements in computer technology it is possible to capture these data using fast hard disks and by addressing large volumes of electronic RAM in the capture PC. At present, the size of each volume of data capture has been determined at 512 Mbytes (approximately 38 seconds of ERS data transmission).

RAPIDS SYSTEM

RAPIDS consists of four major subsystems:

- Tracking of SPOT, ERS and JERS satellites
- Data capture for SPOT, ERS SAR, JERS Optical and JERS SAR
- Frame and data synchronisation
- QSAR processor and QOPT processor

The subsystems are currently configured in such a way that separate PCs are utilised for specific functions.
The orbit planning for ERS, SPOT and JERS takes place on one PC. This is used to send timing information to both the tracking and data receiver control/monitor computers. These computers in turn control and monitor the whole tracking and reception process and return signals via RS232 links for logging of the system operation. The computers also link to various power supplies for control and monitoring and various warning and safety devices.

A second, Pentium based PC is used to set up the tracking receiver, to process the patch aerial signals and to generate signals to drive the aerial. The tracking receiver is a dedicated processor system to lock onto beacon signals and provide patch signal information.

A third Pentium based PC is used to set up, control and monitor the data receiver and data demodulator. The data receiver is a general purpose programmable X-band receiver, operating in the range 8 to 8.4 GHz. There is set of data demodulators for each channel of each satellite. Data capture for specified parts of an orbit takes place on this third PC. Currently the capture capacity of a standard system is selective capture of 0.5 Gbytes of data per orbit per computer. In this way it is possible to run a fourth PC (in parallel) to increase data volumes captured to 1 Gbyte.

Frame and data synchronisation, SAR and optical data processing and the generation of output products takes place on a further Pentium PC. The PC's are connected to each other by fast Ethernet or RS232 links.

ADVANTAGES OF LOW COST LOCAL RECEPTION

Local ground receiving stations are essential in providing a direct link between the data and the use of that data. The advantages are:

1. Investment costs are less compared to large ground receiving stations.
2. Running costs are less compared to large ground receiving stations.
3. Data needs can be tuned to the actual needs of the user of which it is assumed that the user will be the operator of the ground receiving station.
4. Local area reception reduces the long lead times before data actually gets in the hands of the users.
5. The data access is controlled by the user, the user remains autonomous
6. There is no exchange of foreign currency across borders when ordering data at a regional, large ground receiving station.

OTHER MEANS FOR IMPROVING ACCESS TO DATA

Internet is more and more used as a medium for the transportation of small amounts of data, but will, most likely, be used for delivery of large amounts of data in the future. The Internet infrastructure is well structured and well placed in the industrialized countries. In tropical countries the infrastructure is still not well developed and thus unreliable. In these countries people still have to rely on telephone connections in the absence of high-speed connections. However, there are big development on-going to provide a global broadband “Internet-in-the sky”. Two alternatives are mentioned here.
The European SkyBridge system, developed by a consortium, led by Alcatel, France.
SkyBridge is a satellite-based system designed to provide global access to interactive, multimedia communications. Built around a constellation of 80 low earth orbit satellites, SkyBridge provides the communications infrastructure for a full range of broadband services, including Internet access and high speed data communications.
SkyBridge can also provide narrowband services and infrastructure links.
Thanks to its global coverage capability, SkyBridge enables telecom operators and service providers to offer interactive services to professional and residential users

worldwide, regardless of their location or the nature of their local communications infrastructure.

The US-based company Teledesic (shareholders: Microsoft's Bill Gates, Boeing, Motorola and Matra Marconi Space) will create a network to provide affordable, world wide access to telecommunications services such as broadband Internet access and other digital data needs. The service that will use some 288 small telecommunications satellites is intended to start in 2003. The Teledesic system will offer user equipment to access the network. Most users will have access to the network using a 64 Mbits sec^{-1} connection. The user equipment consists of small low-power terminals and antenna's. The laptop-size terminals will mount flat on a rooftop and connect inside to a computer network or single PC.
Compared to standard land line connections, currently running at 33.6 Kbits sec^{-1} , an increase in capacity of approx. 2000 times is expected.

For example: A digital forest/non-forest map of 100 MB will take approximately 12.5 seconds using the Teledesic system and about 25000 seconds using standard land line connections.

Although it seems that the accessibility of data will be improved, using the Internet, it is most likely that due to political reasons ground reasons will always be there. Autonomy is simply said the major reason for people to buy ground stations. As the costs of ground stations will decrease, there will always be a market for low cost ground stations.

LOW COST LOCAL GROUNDSTATIONS: THE WAY TO GO

The key issue in all remote sensing missions is how to get the data/information to the users. There are several ways of doing that. Main aspect to be considered here is the autonomy of users. Users want to be independent, they do not want to be controlled, they simply want control over what to get. The only way of achieving that is to give the local user the tools to receive data and the tools to extract the information locally. A local, low cost ground station seems the only alternative at this particular moment. The Skybridge and Teledesic developments as sketched above could stimulate the access to earth observation data because of their high bandwidths as compared to standard telephone connections. However, the major clients for Skybridge and Teledesic are not the earth observation data users. Their data requirements may therefore be neglected during the development of the two systems.

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TABLES

Current situation	Future situation
Regional ground stations	Local ground stations
One-time data access (unit production)	Continuity in data access (mass production)
High costs	Low costs
Research and Development use	Operational use
Long through-put time	Timely results

Table 1: Trends in Data Reception

FIGURES

Figure 1: RAPIDS system, currently deployed at NLR, Noordoostpolder, The Netherlands.