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REVIEW ARTICLE

Anticipated prospects and civilian applications of Indian satellite navigation services in Sri Lanka

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Abstract The government of Sri Lanka has embarked on a massive development programme of the country in all spheres of the economy, with the conclusion of war in May 2009. Sri Lanka is witnessing a new era with a rapid increase especially in infrastructure development projects. With the annihilation of the threats of terrorism, new prospects in satellite and space related technologies and their applications are flourishing. Navigation satellite (NAVSAT) technology plays the core role in a majority of the modern location based services (LBS) and consequent applications can be productively utilized for the development of the country. Global Positioning System (GPS) technology and related services are currently utilized in numerous location based applications in the country.

India has launched navigation service providing satellite programmes, including a regional navigational satellite system. Whilst being covered under the footprint of Indian navigational satellite programmes, neighbouring countries of India can positively use their services for the benefit of the country through collaborative approaches.

In this paper, positive impacts of 3 Indian Navigational Satellite programmes (GAGAN, IRNSS and INSAT-MSS reporting system) for the civilian applications over Sri Lanka are discussed. Other neighbouring countries covered under the footprint of Indian navigational satellite programmes can also employ these services for the location based applications productively.

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Contents

1. Introduction

The island of Sri Lanka lies in the Indian Ocean between latitudes 5°N and 10°N, and longitudes 79°E and 82°E, separated from the Indian peninsula by the Palk Strait at the Southern tip of India (Fig. 1) with a total land mass of 65,610 km^2 (Navaratne et al., 2005). Sri Lanka experienced armed conflicts with a terrorist group named, ''Liberation Tigers of Tamil Eelam (LTTE)'' since 1983 (Nagai et al., 2007). The country had been divided into two parts, controlled by the government and LTTE with changing conflict front lines in Northern and Eastern Provinces. The main cities including Colombo had high terrorist threats, consequently high security measures have been taken in the country. As a result, there were high restrictions for space related and location based technologies until 2009. After defeating three decades of terrorism through a military action in 2009 (Wheeler, 2012), Sri Lanka stepped ahead into a new era of development. The government embarked on many infrastructure development projects including expressways, international harbours, coal and hydropower plants and airports also covering the areas which were previously under LTTE and considered as war zones, which could lead to rapid developments in most of the industries in the island (Central Bank of Sri Lanka, 2011). With the diminution of terrorist risks new opportunities in applications of space and location based technologies have commenced flourishing along with the ongoing rapid development projects in Sri Lanka.

Figure 1 Location of Sri Lanka.

People used landmarks, celestial bodies, dead reckoning (magnetic compass), radio navigation to satellite navigation systems for navigation purpose over the years (Kayton, 2007). Position, Velocity and Timing (PVT) via satellites are vital services that have come out in recent years. Today a majority of the location based services are hinged on navigational satellites.

Satellite navigation (SAT NAV) system provides pilotage type geo-spatial positioning at anytime of the day under any weather condition. Currently, United States GPS (Global Positioning System) and Russian GLONASS (Global Navigation Satellite System) are the only fully operated global navigational satellite systems (GNSSs). China is developing a global navigation system called COMPASS by enhancing their existing regional navigational satellite system Beidou. In addition, the European Union is developing a global navigational satellite system called Galileo, and scheduled to be fully operative around 2020. In addition, countries such as France, Japan and India are developing their own regional satellite navigation systems (El-Rabbany, 2006).

Whilst being the neighbouring country of Sri Lanka, India has launched several navigational satellite programmes and extended their services in location based technologies. In this paper, anticipated benefits of 3 Indian navigational satellite programmes (GAGAN, IRNSS and INSAT MSS reporting service) on Sri Lanka are addressed.

2. Indian navigational satellite programmes

India commenced its space activities in early 1960s with the scientific investigations on the upper atmosphere and ionosphere above the magnetic equator over Thumba in Thiruvanathapuram city. Since then, India has launched several satellite constellations for telecommunication, television broadcast, meteorological applications, remote sensing, telemedicine, tele-education, direct-to-home services, disaster warning, radio networking, search and rescue operations, space exploration, etc. Indian Space Research Organization (ISRO) has invoked two major satellite systems namely, Indian National Satellites (INSAT) which are placed in geostationary orbits for communication purposes and Indian Remote Sensing Satellites (IRS) for earth observation services. In addition ISRO has launched a navigation satellite programme to provide satellite navigation (SATNAV) services and space science mission for space exploration. ISRO has launched over 60 satellites since the commencement of Indian satellite programme in 1960s, for various scientific and technological applications (Department of Space - India, 2012a).

ISRO has commenced a GPS aided geo-augmented navigation system (GAGAN) with Airports Authority of India to provide satellite based navigation services for civilian and aviation application. The technical demonstration phase of the programme is successfully completed, whilst the final operational phase is in progress Acharya et al., 2007; Kibe, 2003; Rao, 2007a. In addition, ISRO has instigated a regional navigational satellite constellation, namely Indian Regional Navigational Satellite System (IRNSS) as an independent system from current GNSS constellations (Hegarty and Chatre, 2008). Further, INSAT programme facilitates Mobile Satellite System (MSS) reporting services for one-way transmission of position and SOS messages from reporting terminals consist of inbuilt GPS receivers (Bandyopadhyay and Venugopal, 1996).

2.1. The GPS aided geo-augmented navigation system (GAGAN) and anticipated prospects in Sri Lankan aviation

Differential GPS (DGPS) can provide 1–10 m level accuracies only in limited coverage within a 50 km radius area around the reference station (Farrel and Givargis, 2000). Therefore, to get continuity of DGPS locations over a large country or continent for the purpose of civil aviation, reference stations have to be positioned in every 50 km distance, hence would be costly. To provide accuracy, integrity, availability and continuity of positional data for civil aviation, Federal Aviation Administration (FAA) has therefore developed two GPS based augmentation systems frequently called as Wide Area Differential GPS (WADGPS) or Satellite-based augmentation system (SBAS), i.e. Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) (Aab Steven, 2005; El-Rabbany, 2006; Kee et al., 1991).

A Satellite-based augmentation system (SBAS) is an augmentation system supporting wide-area or local-area augmentation, designed for enhancing GNSS receiver accuracy via broadcast signals from additional satellites. SBAS systems consist of several ground stations which are called as Range and Integrity Monitoring Stations (RIMS) located at accurately surveyed positions, which obtain pseudo range and carrier phase at L1 and L2 frequencies and collect broadcasted ephemeris from GNSS satellites (El-Rabbany, 2006; Walter et al., 2010). Also, ground stations have terminals to collect meteorological data and consist of an atomic clock to maintain precise time reference (Rho and Langley, 2007). These data are real time transferred to the Master Control Station regularly via fibre optic cables or an optional VSAT satellite terminal. Satellite ephemeris correction parameters, atmospheric correction model parameters (for both ionosphere and troposphere delays) and satellite clock error terms are computed at the Master Control Center (MCC) and satellite integrity is determined. These correction parameters and integrity information are transmitted to a geostationary satellite. Subsequently, these WADGPS signals are retransmitted to the users over a wide area under the footprint of the geostationary satellite transmission (Rao, 2007a).

Presently, Footprints of Wide Area Augmentation System (WAAS), European Geostationary Navigation Overlay Service (EGNOS), Multi-function Satellite Augmentation System (MSAS) and GPS Aided Geo-Augmented Navigation System (GAGAN) are SBAS systems covering United States (including Alaska and Hawaii), Europe, Japan and Indian regions respectively (Merry, 2007).

GAGAN is a GPS aided SBAS system jointly implemented by Indian Space Research Organization (ISRO) and Airports Authority of India (AAI) with the objective to provide satellite based navigation services with accuracy and integrity required for civilian and aviation applications and for better management of air traffic in the Indian Air Space (Acharya et al., 2007; Kibe, 2003; Rao, 2007a).

GAGAN was implemented in two phases, namely;

(i.) GAGAN-TDS – (Technology Demonstration System)
(ii.) GAGAN-FOP – (Final Operation Phase)

GAGAN-TDS has successfully completed in 2007 and GAGAN-FOP is in progress at the moment, GAGAN is expected to be certified and in operational phase in 2013 (Airport Authority of India, 2012; Indian Space Research Organization, 2012).

Space segment of GAGAN consists of three geo-stationary satellites, including two operational navigation payloads and one in-orbit spare navigation payload. Ground segment of GAGAN consists of a minimum operational configuration including the Indian Master Control Center (IMCC) located in Bangalore, Indian Navigation Land Uplink Station (INLUS), 8 Indian Reference Stations (INRES) and Communication Links at TDS phase. The 8 Reference Stations are connected to IMCC through Fibre optic cables, except the INRES at Port Blair Island which is linked through a VSAT. 18 TEC stations have been established for the development of ionospheric correction model (Kibe, 2003; Nandulal et al., 2008; Rao, 2007a). GAGAN payload characteristics are given in Table 1.

The high position accuracies over the Indian region provided by GAGAN are to be made available for all airports and air fields in Indian Flight Information Region (FIR) facilitating satellite based landing of the aircrafts using SBAS receivers fostering category-I (CAT-I) approach, consequently being a part of global SBAS coverage for aircraft navigation (Sunehra et al., 2008). Requirements for aviation operational performance are given in Table 2 (Keedy, 2001).

Table 1 GAGAN payload characteristics (Source: Indian Space Research Organization).

SI. No	System characteristics	L1 Frequency (1575.42 MHz)	L5 Frequency (1176.45 MHz)
1	Transmitted EIRP (EOC)	30.2 dBW	29.2 dbW
2	Receive G/T	−2 dB/deg K	−2 dB/deg K
3	Bandwith	20 MHz	24 MHz
4	Footprint	Global	Global
5	Feeder Link Frequency	C-band	C-band
6	Transmit Polarization	RHCP	RHCP
7	Type of Antenna	Helix	Helix
8	Antenna Gain	15.8 dB	15.8 dB
9	RF Power rating	40 W	40 W
10	Total Payload weight	50 kg	
11	Power DC	240 W	

Table 2 Aviation operational performance requirements [Source: (Keedy, 2001)].

	Accuracy	Integrity	Time-to-alert	Continuity	Availability
En route	3.7 km (H)	$1–10^{-7}$/hr	5 min	$1–10^{-4}$/hr to $1–10^{-8}$/hr	0.99–0.99999
En-route, Terminal	0.74 km (H)	$1–10^{-7}$/hr	15 s	$1–10^{-4}$/hr to $1–10^{-8}$/hr	0.99–0.99999
Initial approach, NPA and Departure	220 m (H)	$1–10^{-7}$/hr	10 s	$1–10^{-4}$/hr to $1–10^{-8}$/hr	0.99–0.99999
NPV-I	220 m (H) 20 m (V)	$1–2 \times 10^{-7}$ per approach	10 s	$1–8 \times 10^{-6}$/hr in any 15 s	0.99–0.99999
NPV-II	16 m (H) 8 m (V)	$1–2 \times 10^{-7}$ per approach	6 s	$1–8 \times 10^{-6}$/hr in any 15 s	0.99–0.99999
CAT I	16 m (H) 6–4 m (V)	$1–2 \times 10^{-7}$ per approach	6 s	$1–8 \times 10^{-6}$/hr in any 15 s	0.99–0.99999

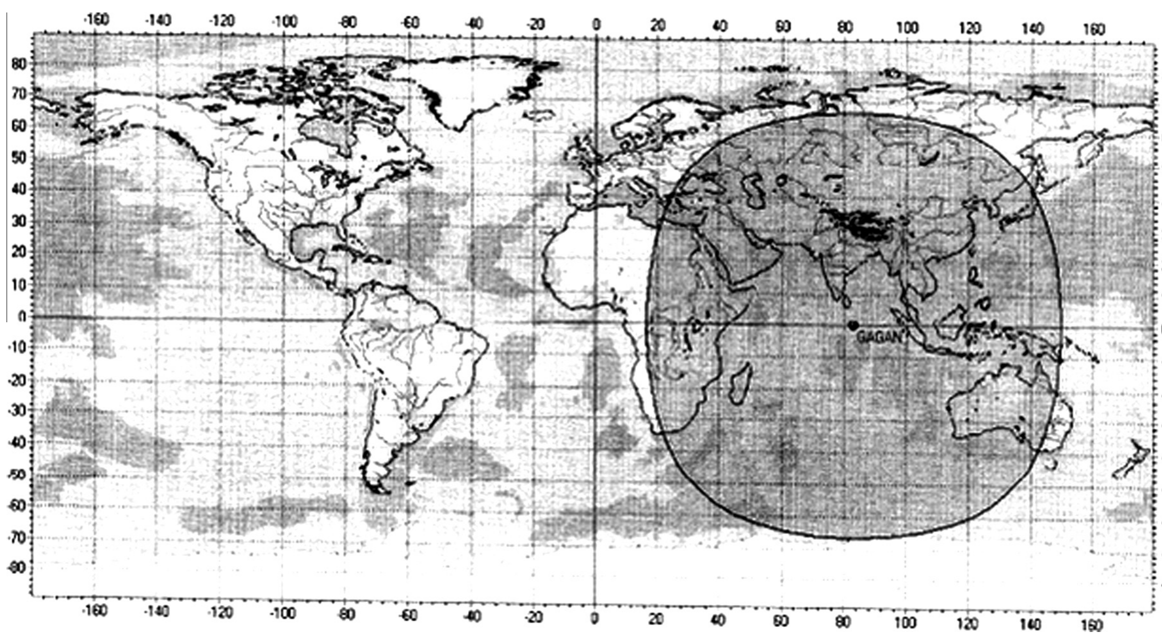

Figure 2 Coverage of GPS aided geo-augmented navigation system (GAGAN) [Source: (Rao, 2007a)].

Upon defeating terrorism, Sri Lanka is stepping towards a new era in civil aviation. Construction of the second international airport in Mattala, Hambantota District is in progress at the moment. With the relaxation of security related measures in 2010, domestic air travel market in the island has also shown a resurgence since the dawn of peace (Civil Aviation Authority of Sri Lanka, 2010). About 7 airlines are providing domestic air travel facilities in Sri Lanka (Civil Aviation Authority of Sri Lanka, 2011) via scheduled and charter flights to destinations such as Bentota, Koggala, Nuwara Eliya, Kandy and Dikwella including a seaplane service from Colombo to Nuwara Eliya. Moreover, it is planned to have domestic air transportation from Colombo to several new destinations, especially to tourist attractions over the island. Further, with the dawn of peace, many international airlines resumed their flights to Sri Lanka. With the rapid increment of the arrival of international tourists in the island, and with ongoing developments in the country, there is a high potential of having increased air traffic in Sri Lankan airspace.

It can be clearly seen that footprints of Indian GAGAN payloads cover entire Sri Lanka and several other neighbouring countries such as Pakistan, Afghanistan, Bhutan, Nepal and Bangladesh (Fig. 2). Therefore, with collaboration with India, these countries can employ the services of GAGAN constellation by properly augmenting ground segments (Airport Authority of India, 2012). Consequently, Sri Lanka can utilize services of GAGAN for international and domestic air traffic management to provide satellite based positioning with accuracy, integrity, availability and continuity for the aircraft navigation in Sri Lankan airspace fitted with SBAS receivers.

By adopting SBAS for aviation, flight delays, diversions and cancellations (DDC) can be minimized, whilst minimizing Controlled Flight into Terrain (CFIT) incidents by 75%. In addition, it enables direct flight paths and reduction of separation minima, which reduce the workload for pilots and controllers, hence air traffic can be significantly minimized, especially in busy airspaces. Further, SBAS facilitates enhanced oceanic air traffic control facility, where ground-based navigation system is unavailable. Also, shorter direct flight paths enabled by SBAS, leads to time and fuel saving. Consequently, decrease of emission of green house gases due to shortened flight paths, results in reduction of air pollution. At the same time, flexible flight paths enabled by SBAS makes weather deviation uncomplicated and also enables reduction of noise in noise sensitive areas (Department of Infrastructure and Transport, Australia, 2011).

Therefore, by employing satellite based augmentation systems for aviation, flight safety can be enhanced while reducing air traffic and environmental pollution, saving time and money for air travel. Hence, the consequent anticipation can be effectively utilized for the Sri Lankan aviation industry through a collaborative approach with GAGAN programme of India upon the completion of FOP and with the implementation of SBAS technology for civil aviation in the future.

2.2. Indian Regional Navigational Satellite System (IRNSS)

Indian Regional Navigational Satellite System (IRNSS) is a regional satellite based navigation system, independent from current GNSS systems, implemented by Indian Space Research Organization (ISRO) to provide reliable position, velocity and timing (PVT) services at anytime over any weather condition over India and neighbouring countries (Hegarty and Chatre, 2008). The space segment of IRNSS consists of 3 geostationary orbit satellites at longitudes 34°E, 83°E and 131.5°E and 4 inclined geosynchronous orbit satellites at 29° inclination and with longitude crossing at 55°E and 111.5°E (Department of Space - India, 2012a; Hegarty, 2012; Li et al., 2011). The first satellite is planned to be launched by the Indian launcher, Polar Satellite Launch Vehicle (PSLV) by 2012–2013 and a full constellation is planned to be completed by 2014 (Indian Space Research Organization, 2012). Space segment is proposed to be augmented with 4 other satellites to make a constellation of 11 satellites to increase accuracy and for better coverage at phase 2 (Neelakantan et al., 2010).

Two types of services that are intended to be provided by IRNSS namely;

(i.) Standard Positioning Service (SPS)
(ii.) Restricted/ Authorized Service (RS)

L5 band (1176.45 MHz) and S band (2492.08 MHz) will be used to carry both SPS and RS services. Binary Phase Shift Key (BPSK) modulation is used in SPS whereas Binary Offset Carrier (BOC (5,2)) modulation is used in RS (Li et al., 2011; Rao et al., 2012). Characteristics of IRNSS L5 band and S band signals are given in Tables 3 and 4 respectively.

Coverage of IRNSS constellation extends from 40°W to 140°W longitudes and 40°S to 40°N latitudes as shown in Fig. 3, where Sri Lanka is located in the zone of preeminent IRNSS coverage with excellent Horizontal Dilution of Precision (HDOP) (Li et al., 2011; Rao, 2007b). Consequently, services and benefits of IRNSS can be gained by Sri Lanka at its highest accuracy, upon the completion of IRNSS constellation in 2014 as expected.

IRNSS ground segment consists of IRNSS Ranging and Integrity Monitoring Stations (IRIM), IRNSS Navigation Control Center (INC), Spacecraft Control Center (SCC), IRNSS telemetry and command stations and CDMA ranging stations. IRNSS Ranging and Integrity Monitoring Stations facilitates one way ranging of IRNSS geo-synchronized satellites by receiving data from the satellites and transmitting to navigation control centre. Ephemeris are predicted and estimated at IRNSS navigation control centre. Further, ionospheric corrections and integrity are determined, whilst corrections for SV clock are calculated in order to maintain IRNSS time at IRNSS navigational control centre. Subsequently, clock and ephemeris corrections are transmitted by INC to telemetry and command stations. Telemetry and command stations receive telemetry and telecommands of the IRNSS constellation and navigational updates are uplinked to the satellites. Spacecraft Control Center is used for the management and maintenance of IRNSS satellite constellation whilst CDMA ranging stations are used for facilitation of accurate ranging from IRNSS satellite and to transmit data to the navigation control centre (Neelakantan et al., 2010; Rao, 2007b; Rao et al., 2012).

As an alternative system for current GNSS, IRNSS can provide satellite based PVT services with excellent Geometric Dilution of Precision (GDOP) in Sri Lanka, hence IRNSS services can be utilized in a vast number of civilian applications in many application areas in the country.

Table 3 IRNSS-L5 band characteristics [Source: (Ganeshan, 2011)].

Service	Frequency band	Centrefrequency (MHz)	Allocated bandwidth	Polarization	Modulation	Code rate (Mcps)
SPS	L5-band	1176.45	24 MHz (1164.45–1188.45 MHz)	RHCP	BPSK(1)	1.023
RS data	L5-band	1176.45	24 MHz (1164.45–1188.45 MHz)	RHCP	BOC(5,2)	2.046
RS pilot	L5-band	1176.45	24 MHz (1164.45–1188.45 MHz)	RHCP	BOC(5,2)	2.046

Table 4 IRNSS-S band characteristics [Source: (Ganeshan, 2011)].

Service	Frequency band	Centre frequency (MHz)	Allocated bandwidth	Polarization	Modulation	Code rate (Mcps)
SPS	S-band	2492.028	16.5 MHz (2483.778–2500.278 MHz)	RHCP	BPSK(1)	1.023
RS data	S-band	2492.028	16.5 MHz (2483.778–2500.278 MHz)	RHCP	BOC(5,2)	2.046
RS pilot	S-band	2492.028	16.5 MHz (2483.778–2500.278 MHz)	RHCP	BOC(5,2)	2.046

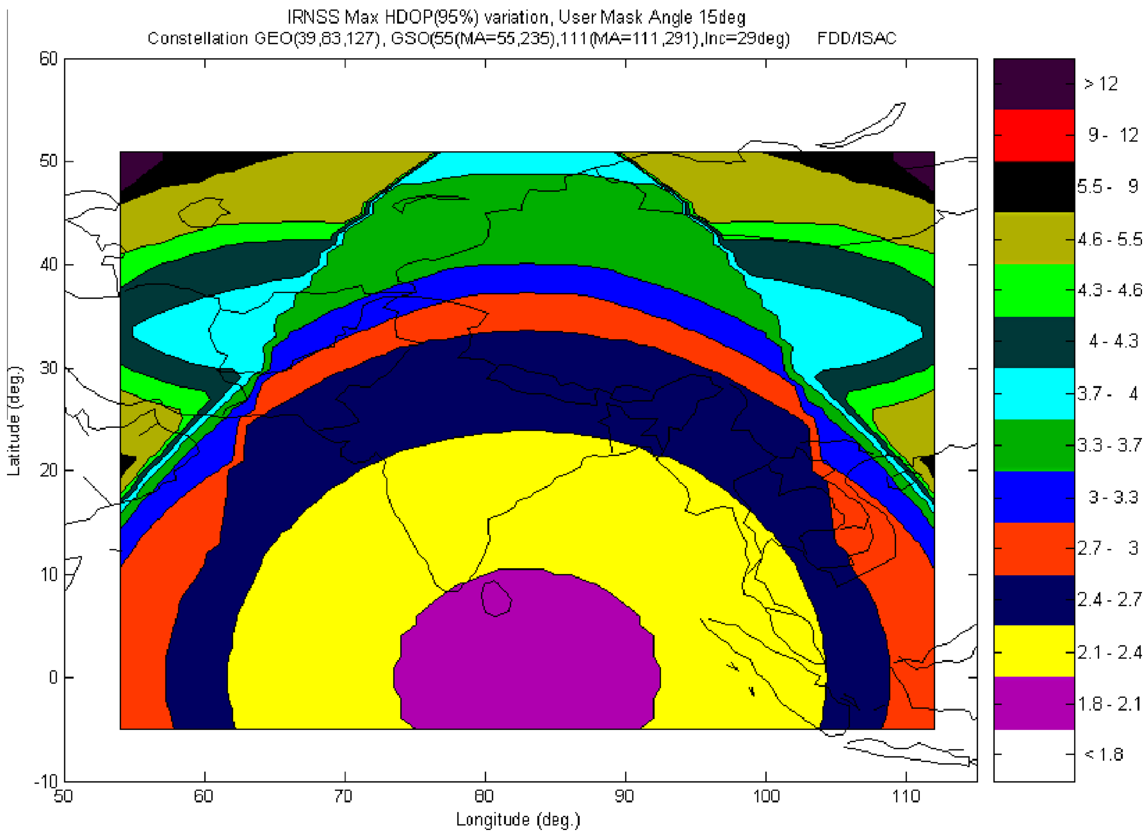

Figure 3 Coverage of IRNSS and maximum HDOP [Source: (Rao, 2007b)].

Upon completion, IRNSS can be utilized in India and neighbouring countries as an alternative for the current GNSS systems available. Several widely used civilian applications of satellite based navigation are listed below. Consequently, Sri Lanka can effectively employ IRNSS services for these civilian applications and location based services, upon the completion of the IRNSS project.

2.2.1. Applications in transportation

With the improvements of intelligent transportation systems through satellite based navigation, safety, traffic management and efficiency of travel can be enhanced, whilst saving fuel and time, consequently reducing emissions. Also, GNSS technologies can be utilized in emergency location services, fleet and vehicle tracking and vehicle navigation services. In addition, Sat Nav based technologies can be effectively used in aviation, by the development of SBAS. (El-Rabbany, 2006; Filip et al., 2002; Jarašūnienė, 2007; Kaplan and Hegarty, 2006; Sadoun and Al-Bayari, 2007).

2.2.2. Applications in civil engineering

Movements of heavy soil and concrete trucks can be optimized through Sat Nav based tracking systems to increase the efficiency of construction sites. Vehicle movements can be monitored easily at the controlling room on a screen, hence can be managed effectively. Autonomous vehicles navigated through Sat Nav based technologies can be utilized for investigations in hazardous and remote areas in civil engineering works. In addition Sat Nav based technologies can be also exploited in monitoring structural deformations (El-Rabbany, 2006; Hudnut and Behr, 1998; Riaz et al., 2006).

2.2.3. Bio-medical applications

Cardiac information of a patient acquired and preprocessed by the portable remote terminal attached to the patient can be transmitted with location information acquired by GNSS module in the terminal to the host computer at a specialist consultant room via GPRS signals. Further, portable GNSS terminals are attached to Alzheimer's and dementia patients for

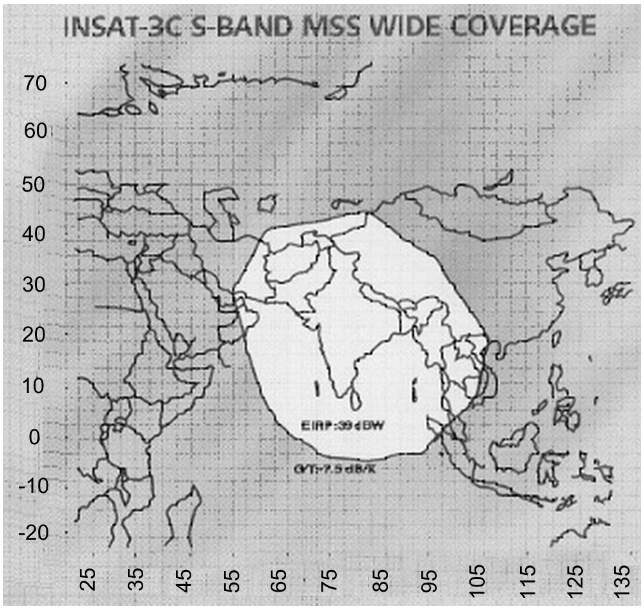

Figure 4 Footprint of INSAT-3C MSS beam (Source: Antrix Corporation Ltd).

real time tracking, hence IRNSS technology can be also used in these applications in the future (Boulos et al., 2011; Lai and Fang, 2007; Landau et al., 2009,). In addition, high accuracy differential GNSS receivers are fixed for gait analysis of patients, to analyse walking speed, step length, step frequency, etc. (Le Faucheur et al., 2008). Seizure signals detected by the smart cap technology are transmitted with the location information of the patient acquired by GNSS module via GPRS technology to a pre-designated mobile number, hence medical aid can be provided immediately to epilepsy patients (Alkan et al., 2006).

2.2.4. Applications in utility management

By integrating GNSS technology with Geographic Information System (GIS) technology, up to date maps of utilities such as electricity, water, sewerage supply lines, etc. can be prepared cost effectively along with other attribute information (El-Rabbany, 2006; Fubara and Yakubu, 2009; Ghassemi et al., 2010; Roberts et al., 2006).

2.2.5. Applications in mining industry

Drilling, vehicle tracking and mine surveying in opencast mines are developed rapidly with the improvements of GNSS Real Time Kinematic (RTK) techniques. Also, Nav Sat based tracking techniques can optimize the management of heavy vehicles in earth moving processes in opencast mines. Further differential GNSS technologies can be utilized as a time effective and accurate method for mine surveying (El-Rabbany, 2006; Gao et al., 2011; Mensah, 2009; Zimmerman et al., 2005).

2.2.6. Agricultural applications

Differential GNSS technology is effectively used in precision farming, soil sampling, fertilizer and pesticide control and yield monitoring in agriculture industry (El-Rabbany, 2006; Gebbers and Adamchuk, 2010; Keicher and Seufert, 2000; Mondal and Tewari, 2007).

2.2.7. GIS applications

GNSS technology is intensively used in GIS to acquire its geographical reference component of data and as a time and cost effective method in cartography. Further, GNSS technology can be used for GIS data verification and mapping (El-Rabbany, 2006; Kaplan and Hegarty, 2006; Sadoun and Al-Bayari, 2007; Senanayake et al., 2012).

2.2.8. Surveying and mapping applications

Nav Sat based technologies are used in cadastral surveying, land and marine seismic surveying, etc. In satellite based surveying, line of sight (LOS) between two survey points is not required, hence surveying can be carried out under any weather conditions even on opposite sides of a mountain. Also, reading obtained via GNSS receiver at one survey station is independent of readings obtained at other locations, hence error at

Table 5 Technical details of the reporting terminal of INSAT MSS Reporting System (Source: Indian Space Research Organization).

Information rate:	300 BPS
	Message length: Up to 40 characters (extendable with external s/w)
Error correction:	Rate ½ FEC and 16-bit CRC
Message transmission:	For handheld terminal:
	3 times randomized transmission in 46 s
	For vehicle-mounted and data acquisition terminals: TDMA with selectable frame time
Modulation:	BPSK
Transmission frequency:	2677.56–2678.56 MHz or
	2688.56–2689.56 MHz
L.O. Stability:	± 1 ppm
Channel spacing:	10 kHz
Transmit EIRP:	For vehicle-mounted and handheld terminals 8 dBW min. over ± 45° off axis
	For data acquisition terminal: 8 dBW min. over ± 15° off axis
GPS receiver:	Built-in
External port:	RS-232C
Power:	12 V DC
Weight:	650 g for handheld terminal
Size:	20 × 9 × 4.5 cm for handheld terminal
Operating temperature:	−10 to + 60 °C

one location is not transferred to the next surveying station. Further, the accuracy in GNSS survey is independent from surveyor's skill. Consequently, several survey teams can work at the same time at different locations within the same project (El-Rabbany, 2006; Kaplan and Hegarty, 2006; Roberts, 2005).

2.2.9. Timing and synchronization applications

GNSS systems can provide precise time; hence it is used for the time stamp in business transactions, wireless communication networks, in power plants for grid synchronization, astronomical observations, etc. (Cantelmo et al., 2009; Kaplan and Hegarty, 2006; Mumford et al., 2006; Powers, 2010).

2.2.10. Disaster management and rescue operations

Nav Sat based technologies can be utilized for disaster mitigation and prevention through hazard monitoring and improvement of rapid location based communication. Further, GNSS technology is highly useful in search and rescue operations during the times of natural and manmade disasters (Aguado et al., 2006; Blewitt et al., 2006; Mahmood et al., 2006; Momoh and Akinyede, 2008).

Further, IRNSS can be utilized in atmospheric, ionospheric, meteorological studies, etc. where regional satellite system consists of geosynchronous orbit satellites and better GDOP can provide better results than global satellite systems (Bevis et al., 1992; Gao and Liu, 2002).

There are numerous civilian application areas which are integrated with Nav Sat technologies, apart from the applications listed above. Thus, Sri Lanka and other neighbouring countries of India can utilize IRNSS and its services for civilian applications in various fields effectively as an alternation for GPS and GLONASS in the near future (Rao et al., 2011).

2.3. INSAT MSS reporting system

Indian National Satellite System (INSAT) consists of a series of geo-stationary satellites launched by Indian Space Research Organization (ISRO) for the purpose of telecommunication, meteorology, broadcasting and search and rescue operations as a joint project of Department of Space, Meteorological Department, Department of Telecommunication, All India Radio and Doordarshan of India (Department of Telecommunications – India, 2012; Ramachandran, 1988; Rao, 2006).

INSAT Mobile Satellite System Reporting Service (INSATMSS Reporting system) is a one-way satellite based transmission system of messaging of position from vehicle mounted, handheld and stationary reporting terminals to a central location (Bandyopadhyay and Venugopal, 1996). Being covered by INSAT MSS transponder coverage (Fig. 4), Sri Lanka can benefit from INSAT MSS services with collaborative approach with India, hence it can be employed for applications such as, fleet monitoring, remote data acquisition, distress messaging and as a request or acknowledgement channel for on-demand services (Department of Space - India, 2012a).

Reporting terminals consist of inbuilt GPS receivers to acquire position and timing for transmission. 3 types of Reporting Terminals have been developed, namely handheld terminals, vehicle acquisition terminals and vehicle mounted terminals. Handheld terminals are used mainly for emergency and distress (SOS) messaging, whilst data acquisition terminals are used in remote data transmission. Vehicle mounted terminals are used in fleet monitoring and automatic transmission of vehicle location at predefined intervals (Avantel Ltd, 2012).

Data acquired through a set of reporting terminals are transmitted to the hub station via time-shared common satellite channel. Subsequently, Network Management System (NMS) at the hub sends data through the internet to the desired destination (Shah et al., 2004). Technical details of INSAT MSS reporting terminal are laid out in Table. 5.

3. Concluding remarks

Sri Lanka is stepping towards a new era of development upon defeating terrorism in 2009. Consequently, future anticipations have flourished in different areas of development in the country. With the ongoing development projects and diminution of terrorist risks, prospects in the fields of satellite based navigation technologies and their applications have emerged.

On the other hand, India has commenced several satellite based navigation programmes and services such as GAGAN, IRNSS and INSAT MSS Reporting system. GPS aided geoaugmented navigation system (GAGAN) is a SBAS system implemented to provide satellite based navigation services for civilian and aviation applications, whilst Indian Regional Navigational Satellite System (IRNSS) is a regional satellite based navigation system, implemented by Indian Space Research Organization (ISRO) to provide reliable PVT services over the Indian region. IRNSS and GAGAN are currently on the progressive phase and expected to be completed in the near future to the operational phase.

However, INSAT MSS Reporting System is currently in operational stage, and utilized in emergency and distress messaging, remote data transmission, fleet monitoring and automatic transmission of vehicle location at predefined intervals.

Being located closer to the Indian peninsula, Sri Lanka is covered under the footprints of these Indian navigational satellite programmes, consequently with collaborative approaches, a majority of these services can be utilized in numerous applications for the benefit of the country in the near future.

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Further reading

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