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Delivery of Broadband Services to Sub-Saharan Africa via Nigerian Communications Satellite

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Abstract

Africa is the least wired continent in the world in terms of robust telecommunications infrastructure and systems to cater for its more than one billion people. African nations are mostly still in the early stages of Information Communications Technology (ICT) development as verified by the relatively low ICT Development Index (IDI) values of all countries in the African region. In developing nations, mobile broadband subscriptions and penetration between 2000-2009 was increasingly more popular than fixed broadband subscriptions. To achieve the goal of universal access, with rapid implementation of ICT infrastructure to complement the sparsely distributed terrestrial networks in the hinterlands and leveraging the adequate submarine cables along the African coastline, African nations and their stakeholders are promoting and implementing Communication Satellite systems, particularly in Nigeria, to help bridge the digital hiatus. This paper examines the effectiveness of communication satellites in delivering broadband-based services.

Keywords

Bandwidth; Broadband; Communications Satellite; HTS; ITU; NIGCOMSAT-1R; OECD

Introduction: What is Broadband?

Broadband has different meanings for different people depending on whether their focus is in terms of capability, capacity, speed, etc. The acceptable baseline for broadband all over the world is the definition of broadband given by The Organization for Economic Co-operation and Development (OECD) which defines broadband as a service (not a technology) that can provide an Internet speed or data transmission rate at least 256 kilobits per seconds (kbps) in at least one direction (Agustin, 2009).

According to Singer (2003), broadband should have sufficient two-way transmission capacity and speed to allow interactive high-quality full-motion video, data and voice applications simultaneously via one "pipe."

The United States Federal Communications Commission (FCC) has up to now used a slightly different terminology in the United States. "High-speed lines" are connections to end-user locations that deliver services at speeds exceeding 200 Kbps in at least one direction (either enabling the end-user to send information – upstream – or receiving information from the Internet – downstream), while "advanced services lines", a subset of high-speed lines, are connections that deliver services at speeds exceeding 200 Kbps in both directions. For the purpose of information collection, the FCC has used "broadband connections" as a synonym of "high-speed lines". In June 2008, the FCC modified its requirements for reporting broadband lines largely based on consumer trends and usage of applications such as high-quality graphics and video telecommunications such as video conferencing, high definition video streaming etc. Specifically, it established eight download speed tiers and nine upload speed tiers, which providers must employ in reporting broadband index. The Sixth Broadband Progress Report increased the Commission's speed benchmark for broadband to 4 Mbps download and 1 Mbps upload because network capabilities, consumer applications and expectations have evolved in ways that demand increasing amounts of bandwidth in the United States. However, there was consideration on the extent of broadband deployment and measure of the current threshold definition to the varying technologies such as fixed-terrestrial broadband,

mobile broadband and satellite broadband (US FCC, 2012). The broadband definition threshold keeps changing on a regional and national basis driven by usage and applications. In Asia, in particular India with over 1.3 billion people, the definition of broadband was revised from 256 kbps to 512 kbps on 1st January, 2011. Considering consumer trends and projections, particularly on mobile network data speeds, the Government of India approved stipulated download speed of 2 mbps for any broadband connection based on any technology with effect from January 1, 2015 based on its national broadband plan (India TRA, 2010). Under the voluntary code of practice of the Office of communications (Of Com), United Kingdom, Broadband speed definitions as used in the code are categorized based on headline or advertised speed by an Internet Service Provider (ISP), access line speed based on maximum speed of the data connection, actual throughput speed based on consumer user experience at a particular time and average throughput speed, which is the average actual throughput speed for each broadband product offered by an ISP (UK Of Com, 2012).

The International Telecommunication Union definition of broadband combines connection capacity (bandwidth) and speed. Recommendation I.113 of the ITU Standardization Sector defines broadband as a "transmission capacity that is faster than primary rate Integrated Services Digital Network (ISDN) at 1.5 or 2.0 Megabits per second (Mbps)" (ITU, 2003). The trend in threshold definition of broadband will continue to change within the foreseeable future due to the level of change of our technologies to support such forecasts driven by demands. For instance, the European Commission provided an update on implementation of national broadband plans in the EU-27 countries, along with Croatia, Norway and Switzerland in which the Digital Agenda for Europe (DAE) required all member states to devise and make operational by 2012, and national broadband plans which would enable the EU to meet the broadband targets for Europe by 2020. Those targets are as follows:

- Basic broadband (512 kbps to 4 Mbps) to all by 2013
- Fast broadband by 2020: broadband coverage at 30 Mbps or more for 100% of EU citizens.
- Ultra-fast broadband by 2020: 50% of European households should have subscriptions above 100 Mbps.

To date, about 22 member states have national broadband plans while the rest is either in review or in the drafting process (European Commission, 2012). Threshold definition of broadband in African nations beyond 256 kbps should be within the context of the level of access to telecommunications infrastructure, usage of applications such as: high-quality graphics, video streaming, video conferencing and the level of new generation networks deployed and envisaged to be deployed within mid-term future projections.

Evolution of Broadband Networks

Before the arrival of the Internet and Packet-Switching Technology, which allows voice to ride over Internet Protocol systems (VoIP) designed for data networks; speech, telegraph, paging and fax systems were run on legacy systems and networks which were basically narrow-band systems.

The arrival of Packet-switching techniques and the Internet resulted in a sharp and continuous increase in demand for converging data networks supporting data, voice, fax and video services, which led to the development of broadband technologies in both satellites and terrestrially based networks (i.e DSL over legacy telephone networks and fiber-based networks, which led to the introduction of multi-core fibers).

Broadband is widely used to describe high-speed access supports today's converged networks of not only voice or data as well as multimedia traffic of high-quality voice, data, graphics, streamed videos and video conferencing.

High speed mobile technologies are becoming increasingly important particularly as services and applications in broadband delivery. However, second generation mobile technologies and their improved versions such as GSM and GPRS (2.5G), cannot be considered broadband, when their download rates reach only 60 to 80 kbps, well short of the OECD threshold. EDGE/Evolved EDGE, W-CDMA (UMTS), CDMA-2000 3G, TD-SCDMA (Chinese National Standard), HSPA and LTE mobile technologies can deliver well above the 256 kbps OECD threshold with higher speed throughputs. Hence, governments of developing countries and their communication regulators should encourage mobile operators to roll out 3G networks rather than investing huge capital sums to upgrade 2G systems.

Why Broadband?

Broadband-based technologies accelerate economic and social development. The introduction of broadband technologies through fiber, satellite and variants of fixed and mobile wireless systems has enabled traditional and new forms of communication to become a reality throughout the world. Most traditional and legacy technologies do not meet the high bandwidth requirements for emerging applications for triple play services (voice, video and data).

The importance of broadband has been highlighted by the Managing Director and Chief Executive Officer (MD/CEO) of NIGCOMSAT LTD; Engr. Timasaniyu Ahmed-Rufai (2012) in the quest for NIGCOMSAT Ltd to target 40% of the Nigerian Broadband Market by 2015 through NIGCOMSAT-1R stated "...In today's challenging economic climate, the dividing line between progress and chaos, the rich and poor nations is the Broadband connectivity. Looking at the near future, Broadband connectivity will be similar to the difference between life and death. For us to be alive as a nation, we must lay a solid foundation for a knowledge-based economy—with ubiquitous broadband and a declining cost of connectivity".

Broadband has the potential to facilitate and boost entire new industries, improve the education system, deliver and enhance health care, enhance farming, monitor and ensure public safety and engage with government. Increasingly, broadband is used to access, organize and disseminate knowledge, increase market productivity, facilitate the generation of new jobs and improve the quality of life through e-Government, distance learning, e-Commerce, e-Banking, e-Village, e-Agriculture and national Security amongst others..

Broadband and Delivery over Satellite

The percentage of the world's population using the Internet is just 28.79%. Africa is the least wired continent in the world, with over one billion people; approximately 90% lack Internet access. Though, Africa has adequate capacity on submarine fiber optic cables deployed along the continental shores, as shown in figure 1 below; however, Africa lacks regionally planned connectivity into the hinterlands and adequate metro fibre rings within cities and rural areas.

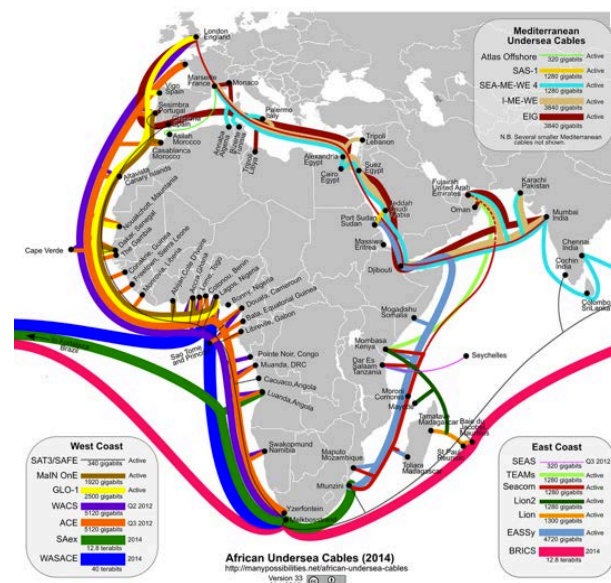


FIG.1 DIAGRAM OF VARIOUS AFRICAN UNDERSEA CABLES
SOURCE: AFRICA UNDERSEA CABLE 2014.

Based on the ICT Development Index (IDI) of all countries in Africa, as reported in the ITU 2010 report-Measuring the information Society (ITU, 2010), Africa is still at an early stage of ICT development as verified by the relatively low IDI values of all countries in the African region. In developing nations, mobile broadband subscriptions between 2000-2009 were increasingly more popular than fixed broadband subscriptions. To achieve the goal of universal access, Communication Satellites and variants of other wireless systems such as Code Division Multiple Access (CDMA), Global System for Mobile communications (GSM), Wireless Fidelity (WiFi) Long-Term Evolution (LTE) etc remain the cornerstones for rapid implementation of ICT infrastructure to complement the sparsely distributed terrestrial networks in the hinterlands.

Satellites representing an attractive option for businesses, government surveillance in rural areas, semi-urban and underserved urban centers, enable new applications that provide services to mobile sites such as ships, trains, planes and vehicles. Aside from fast deployment of satellite services, broadcasting can serve large geographical areas using a single beam. This is one of the major advantages of satellite communications.

The satellite telecommunications technology of today has the potential to accelerate the availability of high-speed Internet services in developing countries, including the least-developed countries, the land-locked and island nations to meet the requirements of

nowadays new knowledge-based economies. There is a close link between the availability of a large-scale broadband infrastructure and the provision of public education, health, trade services and on-line access to e-government and e-trade information.

Satellites can deliver a robust infrastructure, independent of terrains and distances, and as well provide service solutions in various ways servicing-backhaul with last mile via wireless, Internet cafes, or directly to homes via dishes. The effectiveness of satellite broadband is unmatched in emergency situations during natural disasters, acts of terrorism etc.

Satellite system design engineers have developed the enhanced satellite bus with advanced broad-band based communication payloads to support not just broad-band capabilities but also advanced payload capabilities incorporating on-board switching techniques, multi-frequency, multi-polarization and multi-spot beams and large geographical coverage areas, reduced on-orbit cost per transponder, increased service capacity from a single orbital slot, implemented frequency reuse techniques and extended orbital life.

The improvements in satellite technologies, efficiency techniques and methodologies for satellite appendage design, particularly solar arrays and antenna aperture and improved performance in energy/mass ratio of batteries including overall mass/volume optimization of communication satellites has resulted in high powered communication satellites with the capability to support several hundred transponders to meet the increasing market demands made on communication satellite resources for high-definition and digital 3D broadcasting, broadband communications and other satellite-based services (Lawal et al, 2010, 2011, 2012 & 2012a)(Fidler et al, 2002).

High-Definition Television (HDTV), Digital 3D Broadcast over Satellites and the London 2012 Olympic Games.

High-definition Television (HDTV) provides a resolution that is substantially higher than that of standard-definition television (SDTV) improving the quality and performance of direct-to-home and high definition television broadcasting. Standard Definition resolution could be National Television System Committee (NTSC) mostly used in North America and South America with 640 x 480 pixels or Phase Alternating Line (PAL) mostly used in Europe and African countries with 720 x 576 pixels using either 4:3

or 16:9 aspect ratio while High Definition uses far more data for better and enhanced image using higher resolutions. High Definition signal resolution could be 1280 x 720 pixels or 1920 x 1080 pixels with 16:9 aspect ratio (Sugawara et al, 2006). 3DTV is achieved by sending two video streams required to provide the perceived depth characteristics of the displayed images, thus doubling the bandwidth requirements of HDTV. The digital bandwidth requirements to transmit video signals for High Definition Television broadcast and 3DTV calls, with the required color depth, video resolution and frame rate for a single uncompressed HD-quality 3D video stream can be as much as 13 Gbps. To reduce this huge bandwidth requirement, the industry developed standards and formats such as MPEG-2, MPEG-4 etc that set the requirements for audio and video compression for HD video transport over both terrestrial systems and satellites. The goal of these compression tools is to reduce the bandwidth requirements of a video file or stream as much as possible whilst the quality of the video is optimized. This also includes a requirement for migration to enhanced Digital Video Broadcasting (DVB-S2), which increases spectral efficiency of broadcast services.

The recently concluded London Olympics 2012 games is attestation to not just the broadband capability of Communication Satellites but also the HDTV and 3DTV transmission quality assurance. The 2012 Olympic games was the first Genuine Major Carrier Cooperation for DVB satellite television transmissions, achieving historic levels of broadcast quality that was enabled by collaboration of the international broadcast and satellite industries, which jointly launched the first in a series of carrier-ID implementations. The break-through initiative, which benefited billions of viewers, was supported by major broadcasters, satellite operators, encoder and modulator manufacturers and uplink service providers, and proved that it is possible to increase satellite TV quality assurance during major international events. The effort was also supported by four industry associations: the RF Interference – End Users Initiative (RFI-EUI), the World Broadcasting Union-International Satellite Operations Group (WBU-ISOG), the GVF (Global VSAT Forum) and the sIRG (satellite Interference Reduction Group).

Nigerian Communication Satellite (NIGCOMSAT-1R) and Broadband

In Africa, the communications satellites compliment

the inadequate and sparsely distributed terrestrial telecommunications infrastructure. As a means of catching up on the infrastructural gap, communications via satellite and terrestrial wireless systems has had significant success in facilitating information technology policies and infrastructure for most African nations. Initiatives at both regional and national levels have been taken with appropriate policies and frameworks related to ICT network infrastructures and ICT related projects including a campaign of pilot projects to showcase its benefits to the people (Lawal et al, 2012]. Satellite infrastructure remains the most desirable when it comes to point-to-multipoint. Maintenance is simple and affordable free from disadvantages of fiberoptic cable that can be cut or damaged etc as a result of poor urban and regional planning. It is noteworthy that satellite communications outperform their terrestrial counterparts in the sense that they are not affected by natural disasters such as earthquakes, floods, etc.

Satellite communications provide advanced communications infrastructure to regions that do not have adequate terrestrial infrastructure, as the case in Africa. Satellite networks can be rolled out to hundreds or thousands of locations in a fraction of the time required for a comparable terrestrial network to be established. A VSAT installation requires only a single vendor; and multi-vendor coordination is not required. An installation can usually be completed in a matter of hours, no matter where the site is located, meaning complete network deployment can be accomplished in a matter of weeks, rather than months. Satellite network installation and deployment are indeed quick and simple.

High satellite capacity of the order of 100 Gbps coupled with multiple beams and multiple gateways, has already resulted in comparatively low cost satellite bandwidth. Satellite systems are optimized for services like Internet access, Virtual Private Networks (VPN), personal access, etc. The adoption of High Throughput Satellite (HTS) systems has introduced a paradigm shift in satellite broadband access services and the satellite industry. The satellite industry has begun a process of "remaking" the satellite broadband access market into an unprecedented offering that compares favorably to a DSL and fiber-based services in many unserved or underserved markets.

The multi-billion dollar communications satellite industry will continue to evolve with faster, high throughput and innovative systems far superior to the technologies of the 70's, 80's and 90's; to meet the

requirements of the modern digital economy. Recent examples are the High Throughput Satellites (HTS) and the next-generation satellite networks deployed by O3B Networks enabled by the Ka-Band spectrum. The Ka-band spectrum is a new technology with possibilities that allows transmission over a higher frequency spectrum range with frequency re-use up to six times using space diversity, whilst optimizing scarce space resources such as orbital slots and frequencies.

Nigeria is in the history books as the first African country to deploy a Ka-band based Communication Satellite covering the African continent and Europe.

Nigeria's High-Powered, quad-band Communications Satellite carrying Ku, Ka, C and L-Band, had to be de-orbited as a result of an on-board anomaly and re-launched as NIGCOMSAT-1R with few enhancements on 19th December, 2011; and the new satellite is shown in figure 2.



FIG. 2 HIGH POWERED QUAD-BAND NIGCOMSAT-1R SPACECRAFT UNDERGOING COMPACT ANTENNA RANGE TEST (CATR) BEFORE THE LAUNCH CAMPAIGN ACTIVITIES SOURCE: NIGCOMSAT-1R PRELIMINARY DESIGN REVIEW (PDR) AND CRITICAL DESIGN REVIEW(CDR) DOCUMENTS", 2011.

The replacement satellite has better performance parameters based on design inputs related to the weather and climatic conditions of the African Environment, lessons learnt from operations and market experience of the de-orbited first Nigerian Communication Satellite and inclusive participation of Nigerian Engineers and Managers in the Communication Satellite project and program. Communication Satellites over Africa, particularly over the sub-saharan region, should be designed with higher Equivalent Isotropic Radiated Power (EIRP) particularly if the satellites utilizes the upper region of

the satellite spectrum i.e Ku and Ka Band to appreciably compensate for the rain fade column with other complementary measures such as adaptive code modulation (ACM), Uplink Power Control (UPC) system implementation etc.

NigComSat-1R as shown in figure 2 is the second Nigerian Communication satellite with quad-band high power communications; whose geostationary orbit is positioned at 42.5°E with a launch mass of 5,100 kg, and a service life of more than 15 years, while the design life is 22.5 years. The satellite has a reliability value of 99.7% with more than a 75% reliability value at the end of its service life.

The satellite provides Ku-band, C-band, Ka-band and Navigation payloads capability. The Ku-band payload has 14 operational channels, 2 fixed beams over Western and Eastern Africa. The C-band payload has 4 active channels with coverage of Western Africa. The Ka-band payload has 8 channels providing a communications and trunking capability using 3 fixed spot beams over Europe, South Africa and Nigeria. The Navigation payload has 2 receive uplink signals on C-band covering Nigeria and Europe, and 2 transmit downlink signals on L-band: L1 and L5, giving global coverage. Figures 3-11 below show coverage of the NIGCOMSAT-1R satellite across Africa, Part of Europe and Asia including global navigation coverage in the C-Band, Ku Band Ecowas-1, Ku Band Ecowas 2, Ku-Band Asia, Ka-Band European spot beam, Ka-Band Nigerian spot beam, Ka-Band South African spot beam and the Global Navigational band coverages respectively.

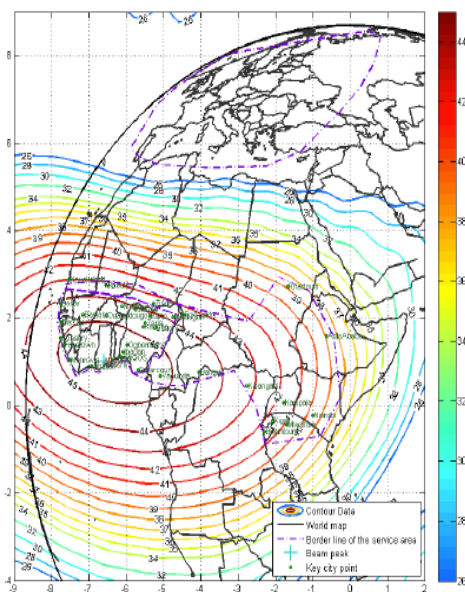


FIG. 3 C-BAND COVERAGE OF NIGCOMSAT-1R OVER WEST AFRICA.

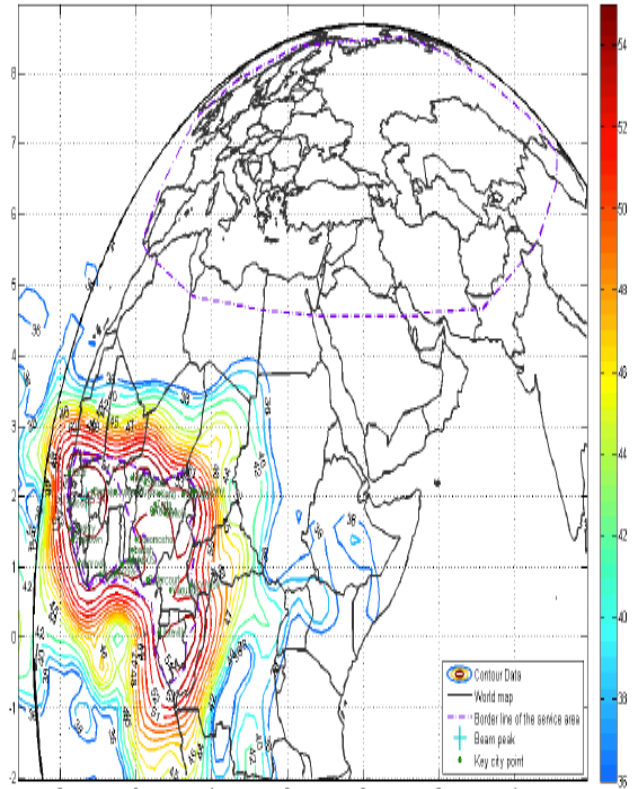


FIG. 4 KU-BAND ECOWAS-1 COVERAGE OF NIGCOMSAT-1R COVERING WEST AFRICA

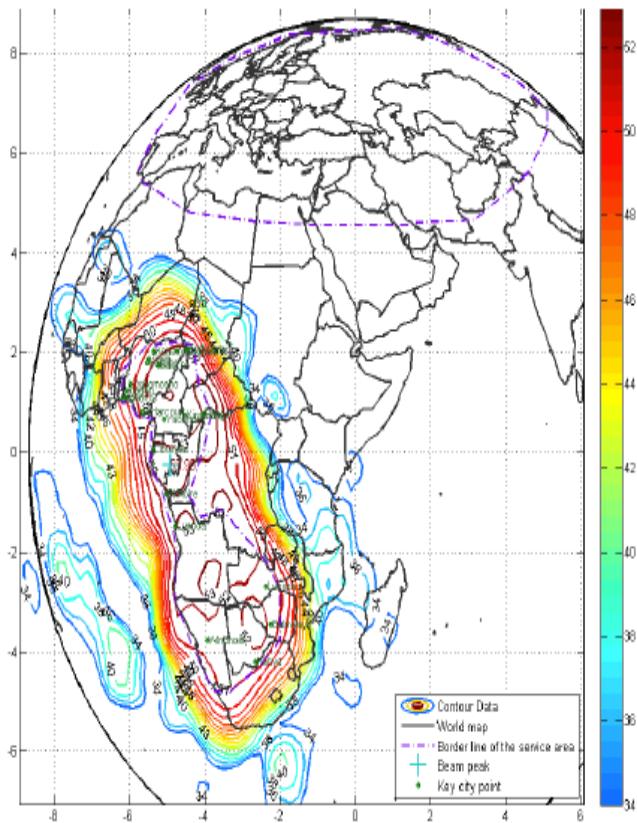


FIG. 5 KU-BAND ECOWAS 2 OF NIGCOMSAT-1R COVERING SOUTH AND EAST AFRICA.

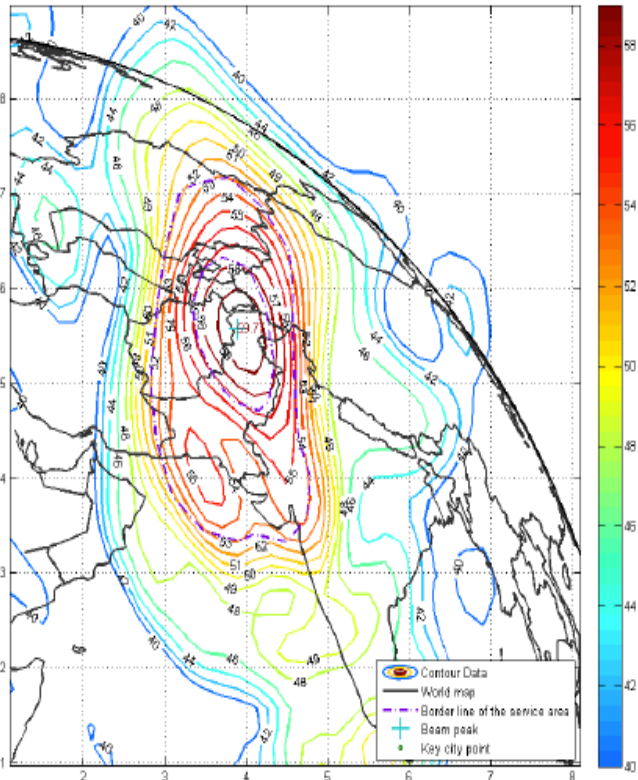


FIG. 6. KU-BAND KASHI OF NIGCOMSAT-1R COVERING ASIA

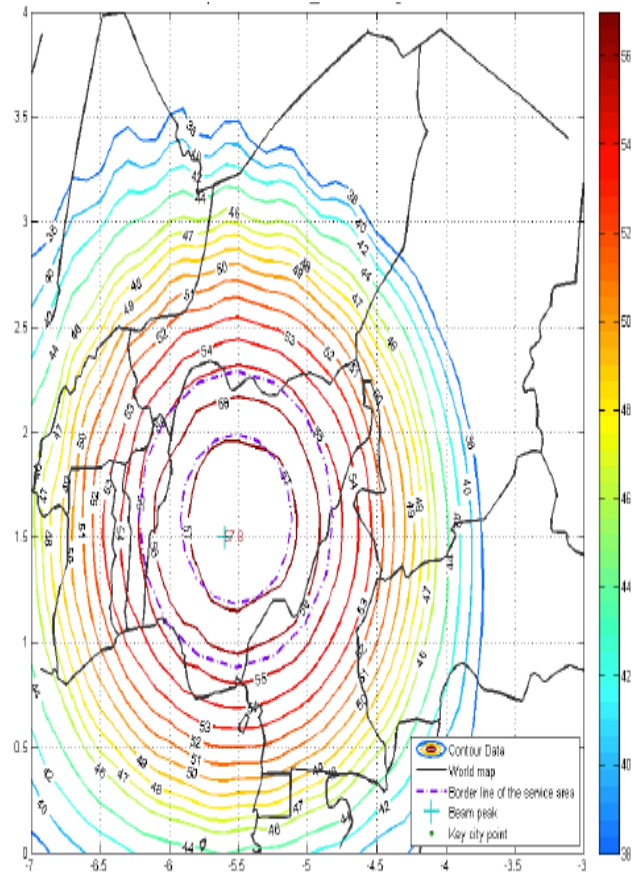


FIG. 8 KA BAND NIGERIAN SPOT BEAM OF NIGCOMSAT-1R COVERING NIGERIA

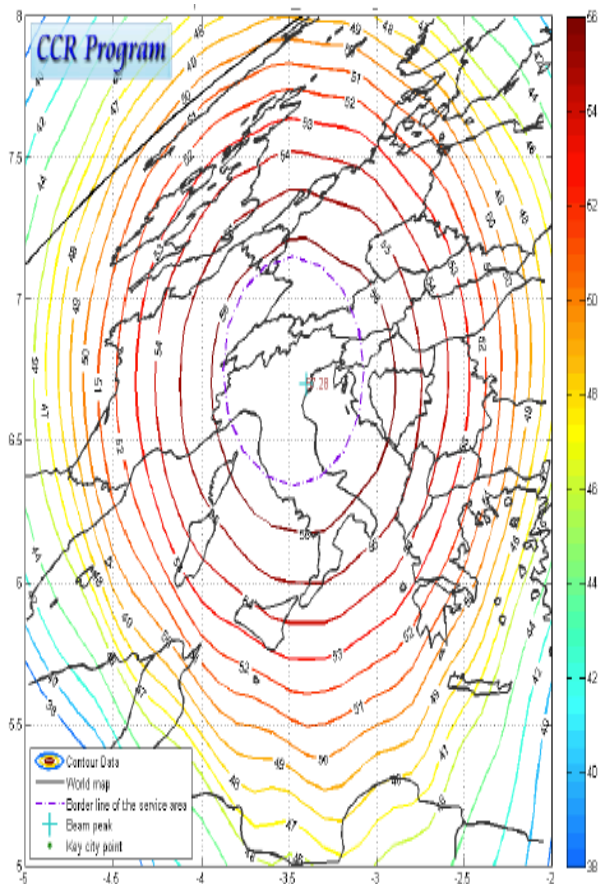


FIG. 7 KA BAND EUROPEAN SPOT BEAM OF NIGCOMSAT-1R COVERING EUROPE

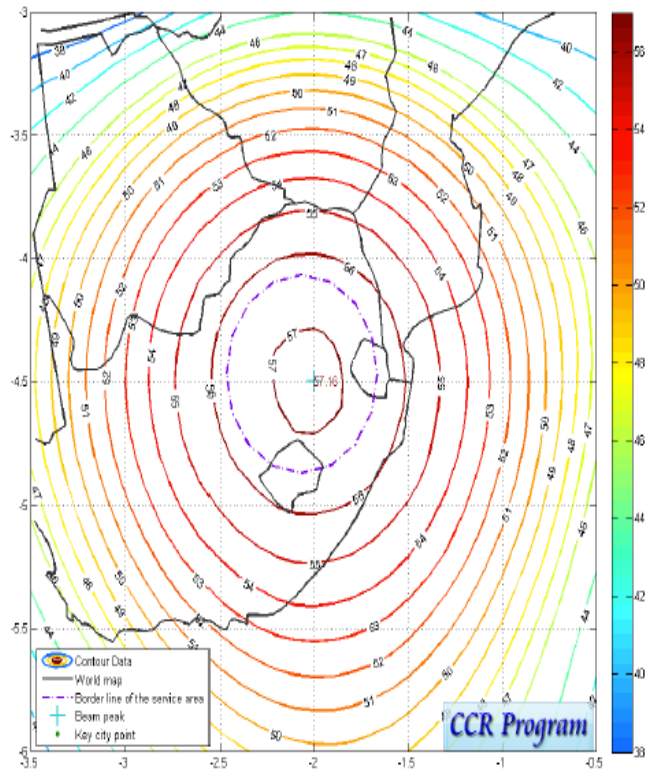


FIG. 9 KA BAND SOUTH AFRICAN SPOT BEAM OF NIGCOMSAT-1R COVERING SOUTH AFRICA.

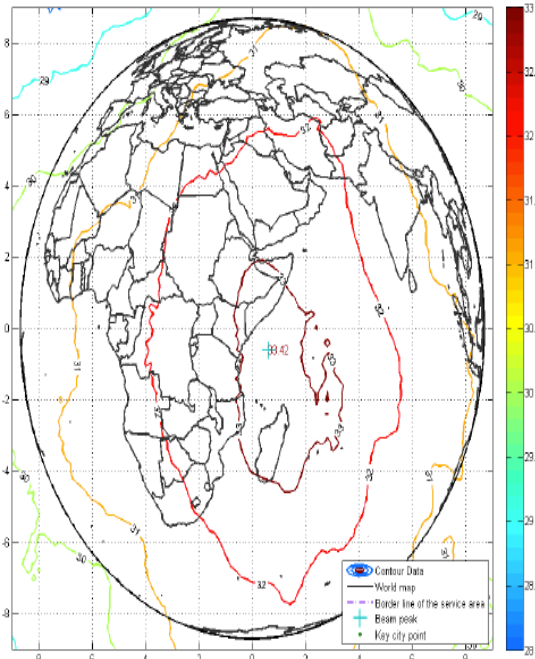


FIG. 10 GLOBAL NAVIGATIONAL BAND COVERAGE OF NIGCOMSAT-1R IN L1-BAND

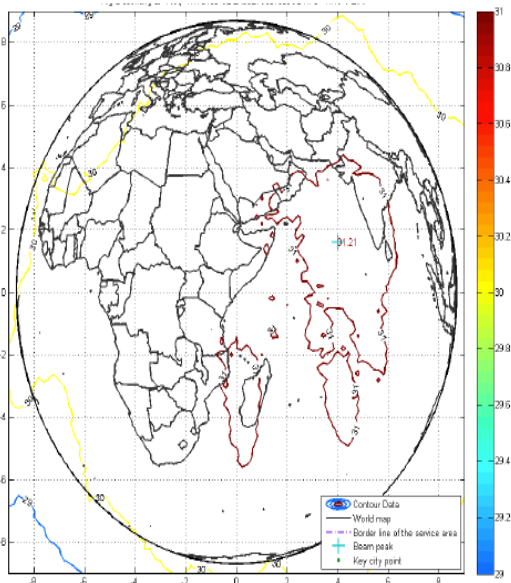


FIG. 11 GLOBAL NAVIGATIONAL BAND COVERAGE OF NIGCOMSAT-1R IN L5-BAND

The spacecraft is designed so that each Radio Frequency (RF) channel meets the specified requirements, works reliably throughout its Service Life including eclipse conditions; and it has a conservative allowance for degradation, wear-out and radiation damage.

With the commencement of commercial operations, after In-Orbit Delivery of the new satellite in March 19, 2012, NIGCOMSAT-1R presently provides ubiquitous broadband services through its various transponders in different bands. The company partnered with the

Main One Cable Company, an undersea Cable operator to expand its coverage into the hinterlands of Africa by strategic deployment and implementation of a teleport hub to serve as an African convergence port where the terrestrial fiber can connect and merge with the Communication Satellite Network.

The Hub is a gateway for all satellite based networks into the Internet Superhighway.



FIG. 12 7.6M CO-LOCATED ANTENNA SYSTEM

SOURCE: NIGERIAN COMMUNICATIONS SATELLITE LIMITED, DECEMBER 2012

NigComSat Ltd was the first to launch one of the most modern teleport services in the Sub-Sahara region, using the iDX 3.0 on DVB-S2 technology and the 2D-16state MODCOD technique on the iDirect hub system, as depicted in figure 13, through a 7.6 m Ku Band Antenna system as shown in figure 12 with a fully redundant 100W BUC solution supporting multi-carriers.



FIG. 13 IDIRECT HUB TECHNOLOGY SYSTEM

SOURCE: IDIRECT AND NIGERIAN COMMUNICATIONS SATELLITE LIMITED, DECEMBER 2012

The Hub is currently used to deploy multiple classes of services on IP broadband networks to various remote locations using variants of Very Small Aperture Terminal (VSAT) systems.

In furtherance of the delivery of a broadband solution, differentiated service classes provide seamless migration of services from other satellites to NIGCOMSAT-1R, thus supporting business development for Nigerians as virtual network operators and internet service providers. Another advanced hub and gateway will be launched soon on a NEWTEC Sat3Play Broadband Gateway System.

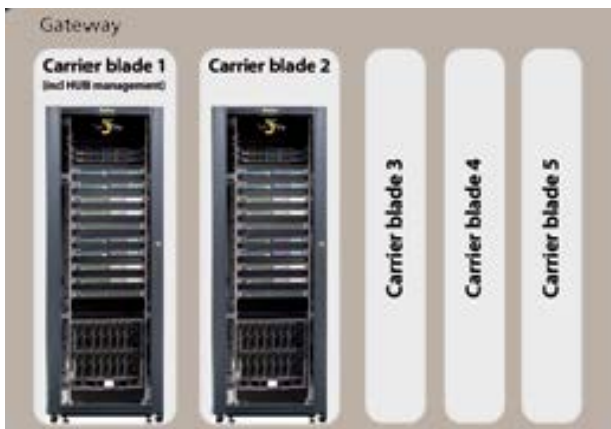


FIG. 14 SAT3PLAY BROADBAND GATEWAY SYSTEM

SOURCE: NEWTEC AND NIGERIAN COMMUNICATIONS SATELLITE LIMITED, DECEMBER 2012

The core of the Sat3Play system, as shown in figure 14, is a DVB-S2 system that enables the provisioning of both basic and complex services to consumer and business markets. The network system is designed for scalability of both traffic and network management capacity with support for a growing range of data, multimedia and voice applications.

The Sat3play management system offers multi service provider platforms for wholesale parts of the system infrastructure with capacity for several large and medium-sized ISPs and VPN operators. The teleport facilities are of utmost importance to the economy of the nation; making available high performance IP broadband networks for education, government, military, healthcare system, enterprise organizations, Upstream Internet Service Providers, Government MDAs, Schools, E-Learning initiative drives, smart communities, e-villages etc.

The differentiated classes of services offered by the teleport is capable to improve the ICT, internet, Broadband penetration and Broadband speed indices of not just Nigeria but the entire African region and

beyond.

To ensure continuity of services including the need for satellites as backup to serve as risk mitigation if the working satellite fails, NIGCOMSAT Ltd with the support of the federal government, as it is a state owned company, is working assiduously to launch two more satellites known as NIGCOMSAT-2 and NIGCOMSAT-3. The entire system network of NIGCOMSAT-1R, 2 & 3 will offer added advantages in reliability, compatibility, security, operations, marketing and increased customer confidence as a client of NIGCOMSAT Ltd. The three communication satellites will strengthen the company's corporate vision as "...the leading communications satellite operator and service provider in Africa." including strong coverage over other continents such as Europe, South America and a steerable spot beam in the Ku-band for wider market capture and patronage.

Conclusions

High Throughput Satellites (HTS) with high efficiency technology has changed the business model. There is a paradigm shift from legacy satellite technologies to satellites with higher bandwidth capacity at lower prices per Megabit, pumping more oxygen into satellite service provider's growth, relevance and profitability.

Multimedia traffic with convergence of voice, video, data and fax are supported by Broadband networks rather than narrow-band networks.

Definition of broadband by African nations should be led by the telecommunications regulatory agencies and commissions based on each African country and needs assessment, demand and the industry statistics at their disposal. Broadband Based Satellites with efficient technologies allows more through put from the same bandwidth, which saves operational expenditure (OPEX). In technical terms, efficiency technologies push more bits (bps) through the same bandwidth. Without broadband-based Communication Satellites, High Definition Television transmission of the Olympic Games to over 6 billion people around the globe would be impossible.

NIGCOMSAT Ltd; a Nigerian-Based Satellite operator and satellite service provider beacons as a bandwidth provider in Sub-Saharan Africa and beyond, a paradigm shift for Nigeria, which previously was just a bandwidth consumer.

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