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IMPLEMENTATION OF ADAPTIVE CODING AND MODULATION FOR SATELLITE COMMUNICATION LINKS IN HEAVY RAIN REGION: AN OPERATOR'S PERSPECTIVE

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ABSTRACT
This contribution presents an implementation of adaptive modulation and coding (ACM) for the real operating satellite- based internet protocol (IP) communication system from the Nigeria communication satellite (NigComSat-1R) very small aperture terminal (VSAT) network. Specifically, different modulation schemes are chosen according to the weather conditions in order to achieve the highest available data rate and preserve the link availability. The experimental results indicate that at least a 24% bandwidth reduction can be achieved with the same data rate by implementing the ACM technique. Further work should focus on the ACM selection strategy based on the peculiarities of the meteorological characteristics in a specific area so that ACM implementation will lead to maximum efficiency in terms of radio resource management and exploitation.

Keywords: adaptive modulation and coding, satellite communication, rain attenuation, tropical, equatorial.

INTRODUCTION
Satellite communications that operate at high frequencies (above 10 GHz) are expected to deliver a wider bandwidth and a higher data rate for multimedia and broadband services. However, such systems have to cope with strong atmospheric impairments, mainly due to rain. This particular impairment is even worse in the tropical regions, which are mostly characterized by heavy precipitation [1]. In this scenario, deep signal fading due to rain will definitely affect the quality of analogue transmissions and increase the error rate of digital transmissions. Such signal impairment can no longer be overcome by the operator increasing the fixed system margin. It therefore requires the implementation of advanced techniques known as Propagation Impairment Mitigation Techniques (PIMTs). To date, various PIMT have been employed by system operators, such as up-link power control, site diversity, time diversity, on board reconfigurable antenna patterns and adaptive coding and modulation (ACM) [2].

The selection of these techniques is based on the status of the radio channel quality that needs to be guaranteed. From among these methods, interest in the ACM PIMT has increased dramatically in recent years due to its ability to counteract atmospheric fading by exploiting different code rates and adaptive waveform and coding schemes [3]-[7]. In fact, current satellite network operators aim to offer broadband internet via satellite for their customers. Besides this, the latest revision of the digital video broadcast-return channel via satellite (DVB-RCS) technique now includes the capability of supporting ACM on the forward and reverse link in the digital video broadcasting satellite-second generation (DVB-S2) standard [8].

Accordingly, in order to fulfil the requirement criteria that have been agreed with customers through service level agreements (SLAs), the ACM techniques appear as one of the promising PIMTs that will be employed by the satellite operators to counteract extra atmospheric fading to preserve the link availability. With this perspective in mind, this work aims to demonstrate the implementation of ACM techniques in the real satellite communication system of the Nigeria communications satellite (NigComSat) network.

This contribution presents some preliminary results on the implementation of ACM in operating NigComSat-1R network. A brief description of the NigComSat-1R network is given in Section 2. Afterwards, the basic principle of ACM and its implementation methodology for the NigComSat network is explained in Section 3. In Section 4, several preliminary results are presented and finally, Section 5 draws some conclusions.

NIGCOMSAT-1R SATELLITE NETWORK
NigComSat is a leading communication satellite operator and service provider in the African region. The first Nigerian satellite (NigeriaSat-1) was successfully placed in orbit in 2003, followed by NigComSat-1 which was launched in 2007, but failed in orbit after running out of power in 2008. After the failure, in 2011, NigComSat-1R (a replacement for NigComSat-1) was launched to provide telecommunications, broadcasting, broadband, security and other communication solutions within the African market, Europe and the Asian markets [9]. Figure-1 shows the NigComSat ground station facilities located in Abuja, Nigeria. The ground stations consist of the Ku, Ka, C and L band facilities.

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Figure-1. NigComSat ground stations location in Abuja, Nigeria[9].

In this work, we assessed the effectiveness of the ACM technique via the NigComSat-1R very small aperture terminal (VSAT) network. Two VSATs were setup to observe the level of rain induced attenuation at the geographic locations within the footprint of the NigComSat-1R satellite as shown in Figure-2. This comprises of an internet protocol (IP) data hub centre in Lagos and two remote VSAT stations in Yenagoa and Maiduguri. It is worth mentioning that all of the stations are located within heavy rain areas, as depicted in Figure-3 and extracted from recommendation ITU-R 837-6 [10].

Figure-2. Locations of the hub center in Lagos and the two VSAT stations in Yenagoa and Maiduguri.

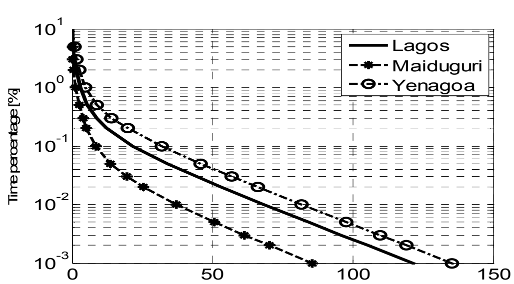

Figure-3. Complementary cumulative distribution function of the rainfall rate in Lagos, Maiduguri and Yenagoa, Nigeria (Extracted from ITU-R 837-6 [10]).

Table-1. NigComSat-1R satellite and site parameters.

Ku band f = Down link 12.50~12.75 GHz Uplink 14.00~12.50GHz			
Satellite Information	Lagos Hub Center	Maiduguri Remote VSAT	Yenagoa Remote VSAT
NigComSat-1R	Lat: 6.4541 Long: 3.3947	Lat: 11.8467 Long: 13.1569	Lat: 4.9847 Long: 6.2642
42.5° East	Altitude:34 m Elevation:44.23°	Altitude:325 m Elevation:53.38°	Altitude:89 m Elevation:47.62°

The NigComSat-1R satellite and its corresponding ground station parameters that have been-used in this work are listed in Table-1.

BRIEF OVERVIEW OF ADAPTIVE CODING AND MODULATION AND ITS IMPLEMENTATION METHODOLOGY

ACM is a smart technique for data rate control that provides dynamic link adaptation to propagation conditions by changing its coding and modulation whilst maintaining a constant symbol rate. In short, this technique dynamically chooses the transmission modulation/coding pair (MODCOD) based on the channel condition (carrier power to noise ratio and interference power ratio) of each receiving terminal [6]. For example, when the link is in clear sky conditions, the system will employ MODCODs with high spectral efficiency, aiming to provide the highest data rate. On the other hand, as the rain affects the link, the ACM controller employs MODCODs with low spectral efficiency and a lower signal to noise plus interference ratio SNIR to maintain the link. This principle is illustrated in Figure-4 below.

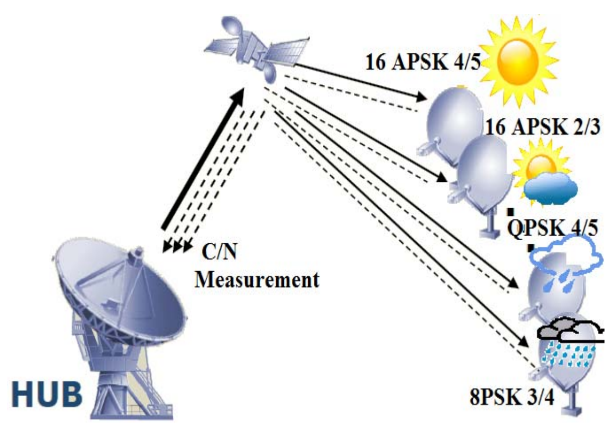

Figure-4. ACM selection strategy according to the weather conditions.

The use of ACM makes it unnecessary for service operators and system designers to trade off the desired link availability and throughput, since the ACM system will adjust according to the weather conditions. The scheme employed in this experimental work is shown in Table 2.

Table-2. ACM selection scheme.

Weather Condition	Constant Coding and Modulation	Adaptive Coding and Modulation
Clear Sky	QPSK 4/5	16 APSK 2/3
Rainy	QPSK 4/5	QPSK 4/5
Bandwidth Required	8.24 MHz	5.31 MHz
Maximum IP Capacity	10 Mbps	10 Mbps
Designed Network Capacity	10 Mbps	10 Mbps

Additionally, it should be mentioned that NigComSat employed iDirect satellite-based IP communication technology that combined hardware and software with advanced features using DVB-S2 and ACM. The system software (iNPT) supports at least 20 types of MODCOD and each scheme provides different bandwidths as can be seen in Figure-5.

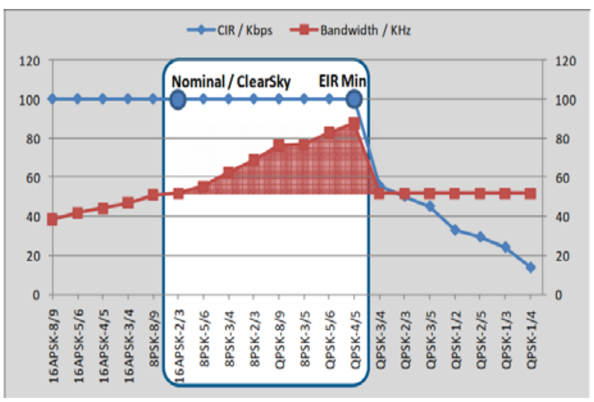

Figure-5. Bandwidth as a function of the ACM modulation scheme from the iDirect DVB-S2 system.

PERFORMANCE RESULTS AND OPERATOR PERSPECTIVES

Figure-6 shows an example of a service outage due to the rain, and the received signal (bottom) and ACM (top) levels are depicted in Figure-7.

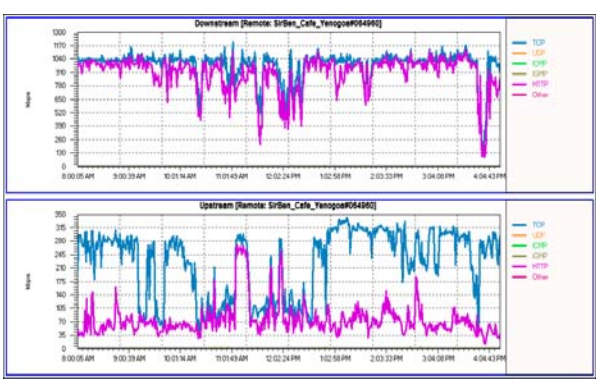

Figure-6. Example of a service outage due to rain.

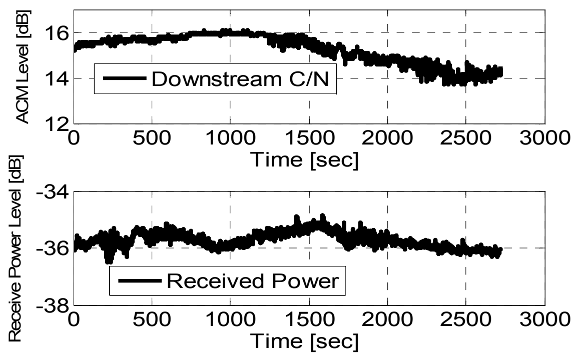

Figure-7. The ACM level downstream and the received power level.

Table-3 shows the results of ACM implementation with respect to different modulation schemes. Notice that different combinations of ACM schemes lead to different data rates and bandwidth utilization.

Table-3. Results of the ACM selection scheme downstream IP Data rate = 5 Mbps, VSAT Service level agreement (SLA) = 99.7 %.

ACM Modulation Scheme Clear sky/ Rain	Symbol Rate (Mbps)	VSAT Bandwidth (MHz)
16 APSK (2/3)/8PSK (3/5)	2.100	2.100
8 PSK (3/4)/QPSK (4/5)	2.535	2.535
8 PSK (3/5)/QPSK (2/3)	3.140	3.140

The above results immediately reflect the performance of the satellite link which is closely tied to the quality of service (QoS) guarantee to the customer. In fact, propagation characteristics such as atmospheric loss play a crucial role in fulfilling the consumer demand requirement. For this reason, ACM implementations are of great importance. In particular, automatically changing the modulation scheme and forward error code (FEC) with respect to the weather condition across the satellite link instead of the service operator having to manually adjust the link power should definitely improve link availability and reliability.

When compared with the links designed using a fixed modulation coding scheme, ACM can increase the throughput of a robust link by allowing it to dynamically adjust to a less robust MODCOD, resulting in higher throughput under clear sky conditions. For example, as the link power is influenced by the rain fading, ACM will try to maintain the link availability by dynamically adjusting to a lower MODCOD order to reduce the data throughput relative to clear sky conditions. In fact, from a business perspective, such services can be provided to customers who are willing to pay for a better QoS and link availability.

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CONCLUSION

ACM implementation has been demonstrated in a real operating satellite system of NigComSat-1R VSAT networks in a heavy rain region of Nigeria. Different ACM modulation schemes were combined in order to assess the effectiveness of ACM in terms of counteracting the rain fading on IP-based communication. The results give a clear indication of the performance of ACM in mitigating rain attenuation in heavy precipitation regions. A 24% improvement in bandwidth utilization following the implementation of ACM when compared to the normal constant coding and modulation (CCM) can be translated into the efficient utilization of transponder capacity. However, one should pay attention to the types of services provided, as the ACM technique is not applicable to broadcasting services that require a constant data rate.

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