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Case study

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Sudanese Communications GEO Satellite: A case study on SUDASAT

Mayada Abdelgadir Ahmed[1*], Rashid A Saeed[2]

[1]*Electronics Engineering School, College of Engineering, Sudan University of Science and Technology (SUST), Khartoum, Sudan*

[2]*Department of Computer Engineering, College of Computers and Information Technology, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia*

[*]Corresponding author
Mayada Abdelgadir Ahmed, Electronics Engineering School, College of Engineering, Sudan University of Science and Technology (SUST), Khartoum, Sudan.

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Abstract
Recently, and to cater to increased needs for communicating through satellite, there has been a growing interest in the marketplace as well as in the research community to develop advanced applications utilizing satellite communications systems. Satellite communications are becoming a common trend in Arab countries. A growing body of literature has focused on developing Geostationary Satellite (GEO) satellites. However, International Telecommunications Union (ITU) have the main coordination for all GEO satellite around the world. The present paper seeks to address the main timelines which relate to a Sudanese satellite. This research study is focused on GEO SUDASAT to offer a variety of communications applications in Sudan. The obtained data is provided from Space Capture ITU software. In this paper, we investigate a proposal for a Sudanese satellite called SUDASAT. The main goal of this paper is to define the SUDASAT technical information which consists of satellite orbital position, the main earth station, and its look angles, the coverage area, launch vehicle, satellite manufacturer and the suitable platform, EIRP, G/T, frequency bands, and several transponders.

Keywords: Technical Information, Geostationary, Fixed Satellite Services, Broadcast Satellite Services, EIRP, G/T, Satellite Platform.

Introduction

Satellite communications can be considered a critical resource for data communications over the world. This significant communications system is essential for agriculture, industry, and a variety of communications services. Nowadays, Arab countries are looking forward to a GEO satellite which can play an important in data communications. Three GEO satellites will cover all of the world [1]. The introduction of such satellite communications systems opens the way for a wide range of applications such as mobile, Internet, and navigation services [2-4]. Over recent years, GEO satellites have received considerable attention in ITU and Arab telecommunications unions.

Satellites are essential in many applications such as communications, military, and earth observations [5, 6]. The need for a Sudanese satellite (which will be called SUDASAT) comes to cover vital services and cater communications requirements of the nation. A communication satellite is an electronic communication package placed in orbit whose prime objective is to initiate or assist in communication transmission of information or message from one point to another through space [7, 8]. Satellite plays a crucial role in life [9, 10].

At present Sudan pays expensive fees to use other satellites. This can be overcome by owning one. Another economic benefit is to rent some of the transponders to neighbouring countries which will provide large income to the country [11]. To achieve these goals scientific background in the satellite field must be required.

The ITU Radiocommunication Bureau Space Capture database is a PC software that supports capturing of space data elements. This release includes graphical interfaces to capture notice information for a variety of space information. Appendix 4 - AP4/II represents the coordination or notification of a satellite network and Appendix 4 - AP4/III introduces the coordination or notification of an earth station. In addition, Appendix 4 (AP4/IV) gives information about notification of assignments to Radio astronomy stations. To submit the Advance Publication of Information (API) on satellite networks or satellite systems, Appendix 4 (AP4/V and AP4/VI) is the main information source. For Broadcasting Satellite Service (BSS) information, Appendices 30(WRC-2000) and 30A (WRC-2000) are provided. As well as for Fixed Satellite Service (FSS) networks, Appendix 30B (WRC-2007) is introduced [12].

In this paper, SUDASAT's main technical information and specifications including services, orbital locations and frequencies, the main earth stations and look angels' calculations, the coverage area, the SUDASAT link budget calculations, and the proposed manufacturer and launcher are presented.

Section II reviews the main concept of the GEO satellite and the African space scene. In Section III, several SUDASAT technical information is explained in detail. Section IV presents the analysis of the results of this study. Section V concludes the results of this paper.

Related Works

Generally, all satellites are earth-orbiting placed at a specific altitude, and round the earth at a special speed based on its types and weight. A geostationary (GEO) satellite is placed at an altitude of approximately 35,800 kilometres directly over the equator that revolves in the same direction the earth rotates (west to east) [13]. Thus, one round trip for the GEO orbit takes the same length of time as the earth requires to rotate once on its axis (24 hours). This special type of satellite appears nearly stationary in the sky as seen by an observer from the earth. GEO satellites can cover a large area, and they are widely used in civil and military fields, such as communications, navigation, early warning, and meteorology.

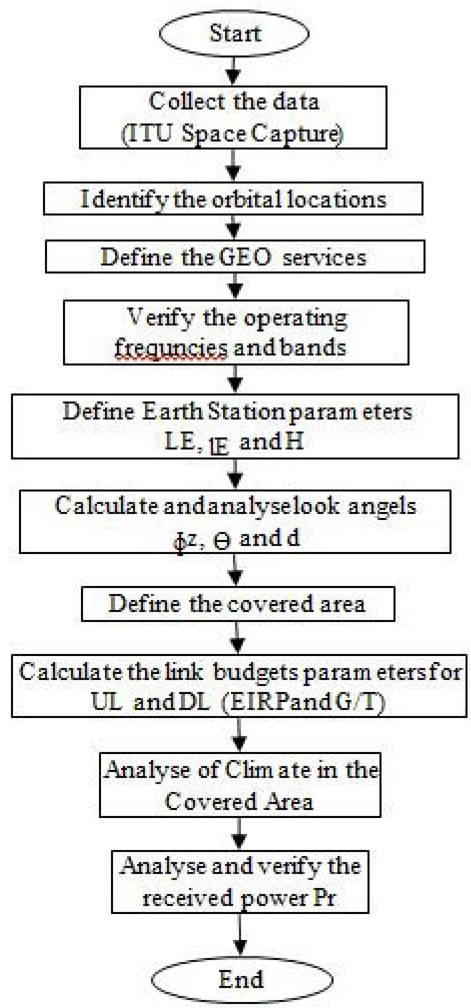
There are many applications for GEO satellites, including earth observation, weather forecasting, satellite radio, and television. The most essential satellites of space-based information networks are usually located in GEO orbit. Every year in the world sometimes GEO satellites fail to get the correct specific orbit or malfunction. According to the statistics of "The UCS database" on average, 28 satellites and 3 rockets are launched into GEO orbit every year, while only 6 or so satellites successfully leave orbit every year. In addition, there are about 2 GEO satellites that fail to get into orbit per year on average, which constitute 7% of the launched satellites. Among the satellites which get into their pre-set orbit, about 5% of them malfunction at the beginning of their life, 10% of them malfunction in the task period, 28% of them malfunction at the end of life, and about 50% of them have extended services [14].

The first African satellite called SunSat-1 was launched by South Africa in 1999 [15]. During the past five years, the African continent records a successful launching of satellites. A total of 41 satellites in space were launched by African states. According to the ITU report, Egypt is a leader with nine launched satellites, followed by South Africa with eight, Algeria with seven, Nigeria with six, and Morocco with three. Ghana, Sudan, Ethiopia, Angola, Kenya, Rwanda, and Mauritius complete the list [16, 17].

In Sudan, there are millions of people with no access to or are simply underserved due to the scarcity of telecommunications infrastructure that exists in the rural areas. Although still a "young" technology, the Internet has had a profound impact in the few years that it has been around. It is now widely recognized that Sudan needs an affordable communications system to meet the needs of society and economic requirements. Many researchers' efforts aimed at studying the main technical specifications of the GEO communications satellite which can support a variety of communications services in Sudan.

Sudasat Specifications

SUDASAT technical information has been introduced for GEO Sudanese satellite. The technical data is obtained from Space Capture ITU software database.



The Flow Chart of the Proposed Data Collection

A. The Services

SUDASAT is a Geostationary Satellite (GEO) to obtain the fixed and continuous signals at any time. The SUDASAT can offer three types of services which describe below. These services are Fixed

Satellite Services (FSS) and Broadcast Satellite Services (BSS) which are: 1)

Broadcast Services

TV and Audio programs DTH (Direct to Home) are broadcasted using digital technology. For examples:

1. Sudanese, Arabic, and International Channels
2. Educational, Health, and Scientific Channels
3. Digital Video Broadcasting

2) Telecom Services

With telecoms services, you can easily deliver your voice, data, and video to anywhere in Africa. For examples:

1. Telephony (mobile phone operator, a fixed-line operator)
2. Facsimile (fax)
3. VSAT network

3) Broadband Services

With the growth of the Internet and other application-driven services, satellite becomes an ideal mechanism to deliver new and modern services to Africa. SUDASAT can provide highspeed access facilitating the most effective use of the Internet's capabilities via satellite.

B. The Orbital Locations

According to the database in the ITU program '' Space Capture'', two orbital locations have been identified for the GEO Sudanese satellite. These two locations are: 23.55° E and 7° W.

The first location has two uplink/downlink beams. This location works in C and Ku bands.

The Second location has only one beam for both downlink and uplink. It works in the Ku band.

C. The Operating Frequencies

The ITU divided the world into three regions. The Sudan country is located in Region One according to the ITU telecommunications service regions. Tables (I) and (II) show the SUDASAT operating frequencies which were found in the ITU program '' Space Capture''.

Table I: The Frequencies of the First Orbital Location

Satellite orbital position	23.55 E
Downlink Frequency Band (C)	4.5 – 4.8 GHz
Downlink Frequency Band (KU)	11.20 – 11.45 GHz
Uplink Frequency Band (C)	6.725 – 7.025 GHz
Uplink Frequency Band (KU)	12.75 – 13.25 GHz
Transponder Bandwidth	36 MHz
No. of Transponders	8 (C band) and 12 (Ku band)

Table II: The Frequencies of the First Orbital Location

Satellite orbital position	7 W
Downlink Frequency Band (KU)	12.1 – 12.4 GHz
Uplink Frequency Band (KU)	14.5 – 14.8 GHz
Transponder Bandwidth	27 MHz
No. of Transponders	12

D. The Main Earth Station and the Look Angles

The main earth station is located in Um-Haraz because it is a terminal area and it doesn't contain high buildings. The land officer remarks that Um-Haraz is a closed area where it is not allowed for anyone to build over 3 floors maximum. Therefore, this region is the appropriate option. Table (III) contains the location parameters of Um-Haraz.

Table III: The Location Parameters of Um-Huaraz

Latitude L_E	15.4078° N
Longitude l_E	32.4942° E
Altitude H	0.382 Km

In this section, a sample calculation for the determination of the SUDASAT parameters is presented. An earth station located in Um-Haraz and SUDASAT located at 23.55°E or at 7°W.

1) The First Orbital Location

The first orbital location parameters are given in table (IV).

Table IV: The Inputs Parameters of the First Orbital Location

Latitude L_E	15.4078° N + 15.4078
Longitude l^E	32.4942° E = +32.4942
Altitude H	0.382 Km
Latitude L_s	0°
Longitude l_s	23.55° E = + 23.55

The orbital parameters for the Um-Haraz, ground station are summarized in table (V):

Table V: The Orbital Parameters of the First Orbital Location

d	36140 Km
θ	69.15°
φ_z	210.64°

2) The Second Orbital Location

The input parameters of the second orbital location are given in table (VI).

Table VI: The Inputs Parameters of the Second Orbital Location

Latitude L_E	15.4078° N = +15.4078
Longitude l_E	32.4942° E = +32.4942
Altitude H	0.382 Km
Latitude L_s	0°
Longitude l_s	7° W = − 7

The orbital parameters for the Um-Haraz ground station are summarized in table (VII).

Table VII: The Orbital Parameters of the Second Orbital Location

d	37661.03 Km
θ	41.57°
φ_z	252.13°

E. The Coverage Area:

The SUDASAT has a multi-beam coverage area. SATSOFT Program was used to draw the coverage of the SUDASAT satellite.

1) The Coverage Area of the First Orbital Location

The receiving test points in Sudan were found from Space Capture Program. Fig. 1 and 2 show the footprints of this location which are found from the information of the downlink beams.

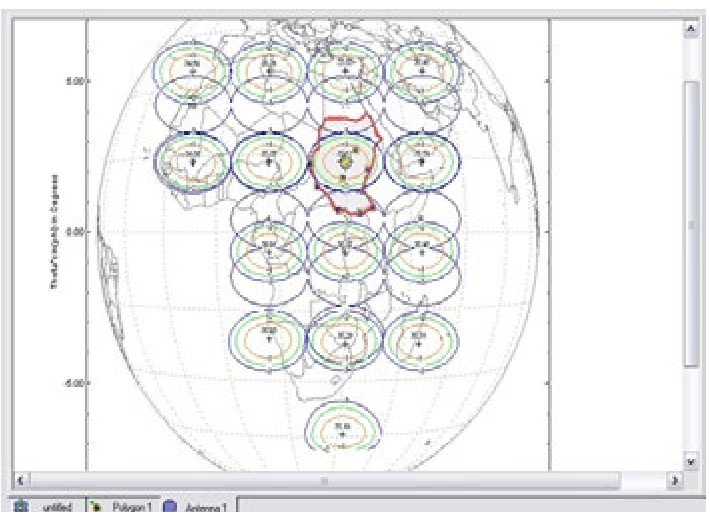


Figure 1: The SUDASAT Footprint

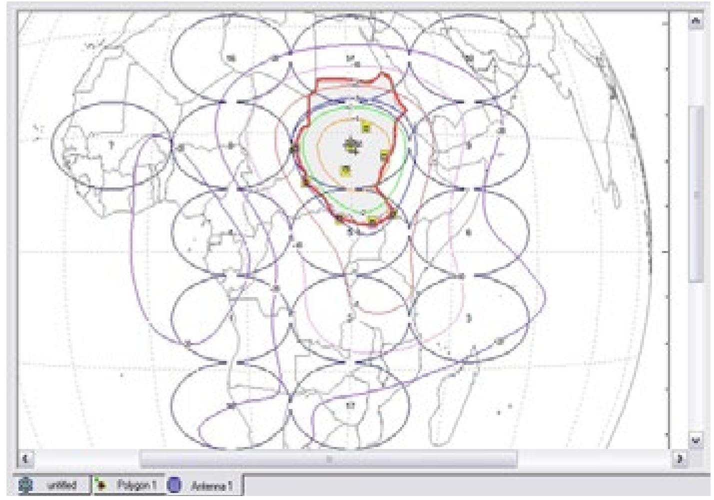


Figure 2: The SUDASAT Coverage Area in Sudan Country

2) The Coverage Area of the Second Orbital Location

The receiving test points in Sudan were found from Space Capture Program.

Fig. 3. shows the footprints of this location which are found from the information of the downlink beams.

Figure 3: The SUDASAT Footprint

F. Link Budget Calculations:

This section presents a sample calculation for the determination of the parameters of the link for the main SUDASAT satellite and the backup satellite by using the link budget equations.

The input parameters were found using the database in the ITU program ‘’ Space Capture’’.

1) The First Orbital Location

The input parameters of the main satellite ‘’SDN00001’’ were found from Space Capture Program. The main link budget parameters are summarized in table (VIII).

Table VIII: The main link budgets parameters of the First Orbital Location

SDN00001	
Satellite orbital position	23.55 E
Downlink EIRP (Max (	45.77 dBW (C band)
	59.97 dBW (Ku band)
Uplink EIRP (Max (	66.26 dBW (C band)
	80.86 dBW (Ku band)
Downlink G/T (Max)	27.22 dB/K (C band)
	27.43 dB/K (Ku band)
Uplink G/T (Max)	9.9 dB/K (C band)
	9.49 dB/K (Ku band)

2) The Second Orbital Location

For the BSS satellite, the input parameters were found from Space Capture Program. The main link budget parameters are summarized in table (IX).

Table IX: The main link budgets parameters of the Second Orbital Location

SDN_101	
Satellite orbital position	7 W
Downlink EIRP (Max (	59.37 dBW
Uplink EIRP (Max (	86 dBW
Downlink G/T (Max)	6.5 dB/K
Uplink G/T (Max)	8.45 dB/K

G. Analysing of Climate in the Covered Area:

Rain attenuation increases with increasing frequency and is worse in the Ku band compared with the C band. The impact of the rain on the power of FSS services will not be calculated because it has no significant impact. Also, in the uplink case, there is no impact because the power of an earth station can be controlled by increasing or decreasing the power level as in Um-Haraz. But the satellite power level cannot be controlled so the rain attenuation will be calculated in this case (downlink case) for BSS services as in the following:

Downlink EIRP (Max(	59.37 dBW (Ku band)
Rain Attenuation	0.366 dB
Atmospheric Absorption	0.11 dB
The Total Power	59.846 dBW

H. The Proposed Manufacturer

A satellite system in its entirety is costly to implement, but the technology provides versatility and flexibility that are potentially greater than that of any other telecommunications technology. The cost of space segment implementation ranges from approximately $250 million for one conventional bent-pipe satellite to more than $10 billion for a complete DTH system.

Both Thales Alenia Space and Astrium companies have the same level of experience and quality of their products. But the proposed manufacturer of SUDASAT will be Thales Alenia Space Company because it has an excellent relationship with Sudan country. For example, UmHaraz deals with the company to get the receiving equipment that Um-Haraz needed. Also, Khartoum Airport brings its VSAT equipment from this company.

Spacebus is a satellite bus produced at the Cannes Mande lieu Space Center in France by Thales Alenia Space. Typically used for geostationary communications satellites, fifty-two have been launched since development started in the 1980s. Spacebus-3000 Platform will be proposed for SUDASAT. Both classes B and C can be chosen.

I. The Launcher

The proposed launcher company will be Ariane 5 ECA because it has an excellent experience compared with other launchers. In addition, its port is more suitable to launch a GEO satellite into its orbit because this port is near to the equatorial plane as mentioned above. In the last years, all the countries which want to launch a satellite go to Ariane 5, and all its launching is successful.

Results

In this section, SUDASAT GEO satellite technical information was carried out to introduce the Sudanese communications satellite. The principal findings of this study are based on the Space Capture ITU database. This work aimed to give an overview of the SUDASAT specifications. Tables (X) and (XI) show the technical information of the first orbital location and the second orbital location respectively.

Table X: The First Orbital Location Technical Information

SDN00001	
Satellite orbital position	23.55 E
Launch Vehicle	Arian 5
Satellite Manufacturer	Thales Alenia Space
Downlink EIRP (Max(	45.77 dBW (C band)
	59.97 dBW (Ku band)
Downlink G/T (Max)	27.22 dB/K (C band)
	27.43 dB/K (Ku band)
Uplink G/T (Max)	9.9 dB/K (C band)
	9.49 dB/K (Ku band)
Uplink EIRP (Max(	66.26 dBW (C band)
	80.86 dBW (Ku band)
Downlink Frequency Band (C)	4.5 – 4.8 GHz
Downlink Frequency Band (Ku)	11.20 – 11.45 GHz
Uplink Frequency Band (C)	6.725 – 7.025 GHz
Uplink Frequency Band (Ku)	12.75 – 13.25 GHz
No. of Transponders	8 (C band) and 12 (Ku band)

Table XI: The Second Orbital Location Technical Information

SDN__101		
Satellite orbital position	7 W	
Launch Vehicle	Arian 5	
Satellite Manufacturer	Thales Alenia Space	
Station Keeping Co-location Accuracy	± 0.1° E-W & ± 0.1° N-S	
Downlink EIRP (Max(	59.846 dBW	
Downlink G/T (Max)	6.5 dB/K	
Downlink C/N (Max(	14 dBW	
Downlink C/No (Max(	88.3 dBHz	
Uplink G/T (Max)	8.45 dB/K	
Uplink EIRP (Max(	86 dBW	
Downlink Frequency Band (KU)	12.1 – 12.4 GHz	
Uplink Frequency Band (KU)	14.5 – 14.8 GHz	
Transponder Bandwidth	27 MHz	
Polarization	CL	CR
No. of Transponders	12	

Conclusions

The main specifications of the Sudanese GEO satellite called SUDASAT are researched in this paper. Geostationary satellite (GEO) has gradually become a trend for a future satellite in Africa due to the great application value. Considering this importance, Sudan country is looking forward to a GEO communications satellite. In this paper, SUDASAT technical specifications include the main services, orbital locations, and frequencies, the main earth stations and look angels' calculations, the coverage area, the SUDASAT link budget calculations, and the proposed manufacturer and launcher are presented. The data was obtained from ITU Space Capture database software. Communication between places, which are far apart, is difficult due to a challenging climate, missing land-based infrastructure, and a lack of suitable satellite systems. A growing interest in Africa for economic reasons and the recent developing changes in climate causes many parties to see greater use of satellite in Africa in the future and an increasing need for infrastructure. Thus, for Sudan's future military and civilian needs, combined with the development trend of modern GEO satellite technology, the preliminary proposal for the development of the SUDASAT GEO satellite is given.

Declarations

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Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Statement

Hereby, the authors consciously assure that for the manuscript / insert title/ the following is fulfilled:

a) This material is the authors' own original work, which has not been previously published elsewhere.
b) The paper is not currently being considered for publication elsewhere.
c) The paper reflects the authors' own research and analysis in a truthful and complete manner.
d) The paper properly credits the meaningful contributions of co-authors and co-researchers.
e) The results are appropriately placed in the context of prior and existing research.
f) All sources used are properly disclosed (correct citation). Literally, copying of text must be indicated as such by using quotation marks and giving proper reference.
g) All authors have been personally and actively involved in the substantial work leading to the paper and will take public responsibility for its content.

Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Availability of Code

The codes generated during the current study are available from the corresponding author on reasonable request.

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