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SATELLITE COMMUNICATION SYSTEM OPTIONS FOR RURAL APPLICATION IN AFRICA

by

S.H. Mneney*

ABSTRACT

Developments in telecommunications in the rural areas of many Third World countries have been neglected due to high investment and operating costs of linking widely scattered points over hostile topography by terrestrial links. Satellite links, with the advantage of total coverage, flexibility and more rapid installation, offer an alternative approach. Recent developments in Satellite communication technology, make possible the application of cost-effective thin route services to rural areas of developing countries. This paper investigates the possible services and satellite system options for rural application in Africa.

1.0. INTRODUCTION

Planning of telecommunications networks is based on projected demand which is made possible by extrapolation of traffic figures from existing networks. In most rural areas of developing countries such networks do not exist and hence demand cannot be quantified. The philosophy of planning a rural communications network based on projected demand is therefore not applicable. In its "basic need" telecommunication service planning the ITU proposes installing a community telephone to each community with 10,000 people (1). Future expansion can then be based on projected traffic through these networks.

It is due to the high investment and operating costs required to run a terrestrial telecommunications network to link widely scattered areas, that the rural areas have largely been neglected, despite their high economic potentials. Recent developments in satellite communications now offer an alternative solution to the problem of communication in the rural areas of developing countries.

Satellite networks have the advantage of total coverage, flexibility and rapid deployment. Such network have, so far, been used mainly to transfer information among developed countries and to enhance their regional and domestic communications. The majority of developing countries gained only in their external telecommunications, which link their urban areas to the outside world. As a result the rural areas have experienced very little change.

Currently, there are a few satellite network options for rural application in Africa. INTELSAT has introduced transponders with high gain settings which make possible thin route services requiring low cost ground stations(2). A regionally shared satellite which could provide, among other services, rural telecommunication in Africa has been proposed in (3). The GLODOM system is a concept proposing a global approach to providing domestic services for rural

* Senior Lecturer, Department of Electrical Engineering, University of Dar es Salaam.

application in all the rural areas of the developing countries (4). This paper investigates the utility of these options in rural telecommunications applications in Africa. The basic ground station, the link parameters and the overall network are proposed for the three options.

Investment costs, operation costs and the viability of the networks are also compared. Section 2 describes the services that can be offerred and their corresponding ground stations. The network options are described in section 3 and their comprison is made in section 4.

2.0 RURAL COMMUNICATIONS SERVICES

The type of two-way services that can be offered to the rural areas include telephone, telegraph, telex and data services. The broadcast type of services include radio and television. New services which are suitable for education, information and data dissemination, which may be offered economically to the rural areas, have been defined in (5). These services include still pictures with speech teletext with speech, silent teletext, and scribophone. These one-way services are broadcast type and can be distributed over narrowband satellite channels. The possible service can be classified into three categories according to the type of earth station in use. Such an earth station will depend on availability of primary power and intended investment. These earth stations are described below:

2.1 The Basic User Earth Station

This will consist of a standard Z-earth station which can provide a minimum capacity of one telephone circuit (6). It will have one carrier for transmission and one carrier for reception. The basic building blocks are shown in fig. 1. The station parameters are given overleaf:

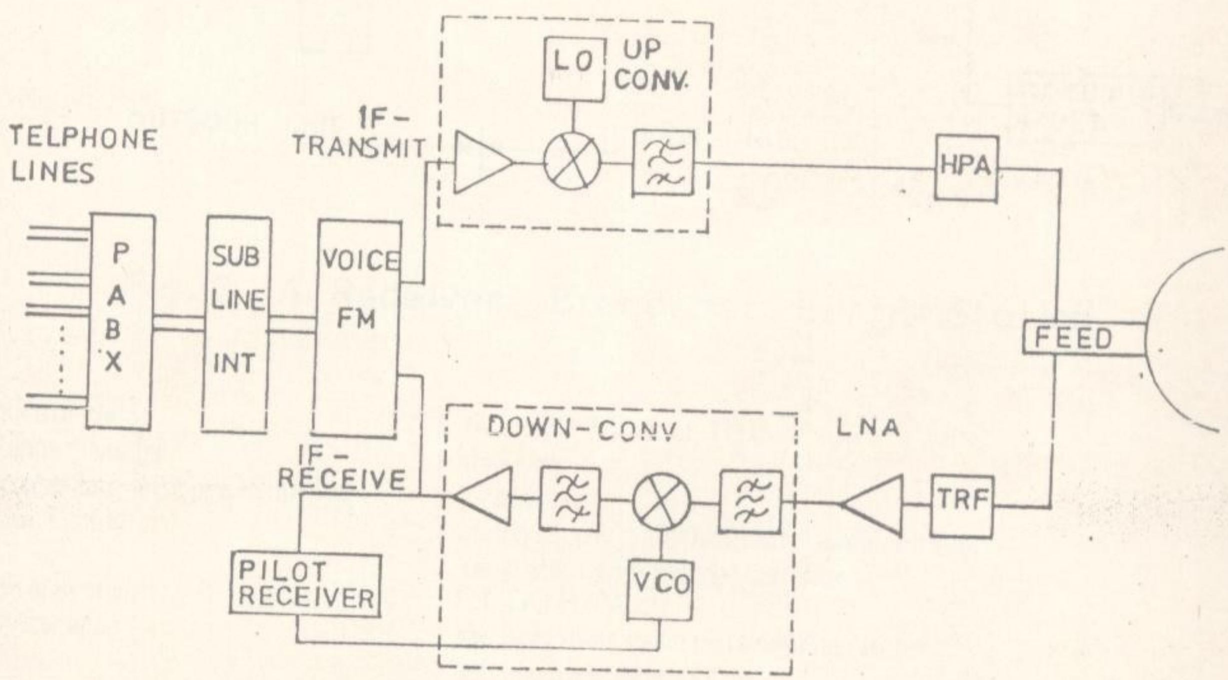

Fig.1: The basic user Earth Station

Figure of Merit	: G/T = 22.7 dB/K at 4 GHz
Antenna Diameter	: d = 5.0m
Uncooled LNA (parametric)	: 80K
Transmission HPA	: 30 watts
Power supply	: solar energy
Type of system	: DM/PSK/FDMA or CFM/FDMA
Services possible	: Telephone, Telegraph, Telex, Teletext, Scribophone, Still-pictures
Service area	: can collect traffic from up to 20 neighbouring communities by radio telephone or direct lines

2.2 Broadcast Receive Only Terminal

This type of earth station is able to receive radio and television broadcast: it has no transmission capability. The station parameters are given below and the circuit is shown on fig.2.

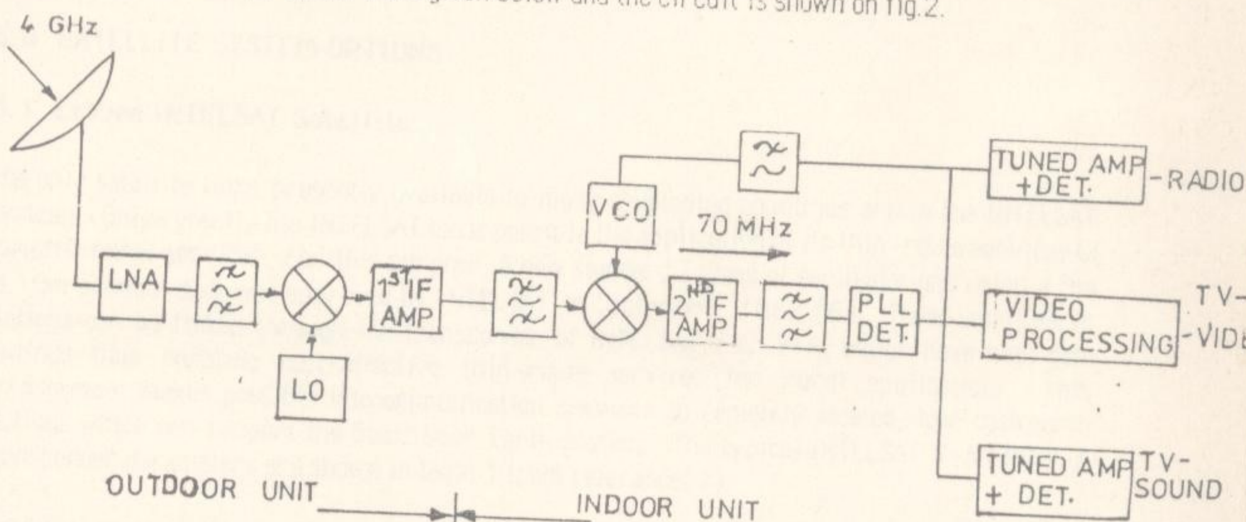

Fig. 2 : A Receiver Broadcast Earth-Station

Figure of Merit	: G/T = 22.7 dB/K at 4 GHz
Antenna diameter	: d=5.0m
Uncooled low noise pre-amplifier	: T=80K
Power supply	: mains supply, intermittently operated diesel generators with storage batteries
Type of system	FM/TV, FM/RADIO
Service area	: can distribute radio and television to neighbouring communities

2.3. A Multipurpose Rural Earth Station

This earth station has the capacity of at least one telephone circuit. It is also able to receive radio and television broadcast. The station will have the following parameters:

Figure of Merit	: G/T = 22.7 dB/K at 4 GHz
Antenna diameter	: 5.0m
Uncooled LNA (parametric)	: T = 80K
Transmission HPA	: 50 watts
Power supply	: mains supply, intermittently operated diesel generators with storage batteries
Type of system	: DM/PSK/FDMA or CFM/FDMA TV/FM, RADIO/FM
Services possible	: TV, Radio, Telephone, Telegraph, Telex, Teletext, Scribophone.
Service area	: can collect traffic from neighbouring communities using radio telephone or direct lines and can distribute TV and Radio by radio links to the same communities.

The circuit diagram is a combination of fig.1 and fig.2 with the wideband and narrowband services suitably separated by filters.

3.0 SATELLITE SYSTEM OPTIONS

3.1 Leased INTELSAT Satellite.

The only satellite links presently available to many developing countries are in the INTELSAT Systems. Only recently has INTELSAT made possible the application of its thin-route services to domestic rural services. For this purpose, a new standard Z class of earth stations using 4.5m to 10m antenna dish was approved by INTELSAT in September, 1982 (6). These small earth stations can be linked through the transponder of INTELSAT V or V-A, which have high gain settings thus enabling cost-effective thin-route services for rural application. This arrangement makes possible telecommunication services to remotely located, low-cost earth stations which can support the Basic User Earth Station. The typical INTELSAT V-A AND V-A transponder parameters are shown in table 1 from reference(7).

The rural earth stations will be linked by dedicated carriers (one for transmission and one for reception) via the INTELSAT transponder to a standard B earth station, which will connect the traffic into a national grid network or link it to other rural subscribers. Communication between rural subscribers will thus be by double hop giving delays in conversation in excess of 0.58 sec. The standard B earth station acts as a concentrator and a circuit switch; it thus eliminates the need for expensive SPADE type equipment at each rural terminal. Further, the standard B earth station can be used for external (international) telecommunications. The channel capacity, as computed in the link power budget of table II, is limited in each direction according to fig.3 for the same carrier-to-noise ratio performance.

The transponder will be accessed by two levels of SCPC carriers, depending on the transmission direction. The transponder can support a maximum of 112 half circuits in each direction, while maintaining the required ground station system performance. If voice activation (VOX) is employed the transponder can support a maximum of 280 half circuits in each direction. This is equivalent to 280 telephone circuits.

The required C/No is given by:

$C/No = Eb/No + 10 \log R$, where

C/No is the carrier power to noise spectral density ratio,

Eb/No is the bit energy to noise spectral density ratio,

R is the bit rate, here assumed to be 32K bit/s

With rate 1/2, 8-level, soft decision FEC scheme and a constraint length K = 3 (which offers a coding gain of 3dB) the required C/No is 50.45 dB-Hz. The channel assignment is made as shown in fig.4. This arrangement gives minimum intermodulation distortion.

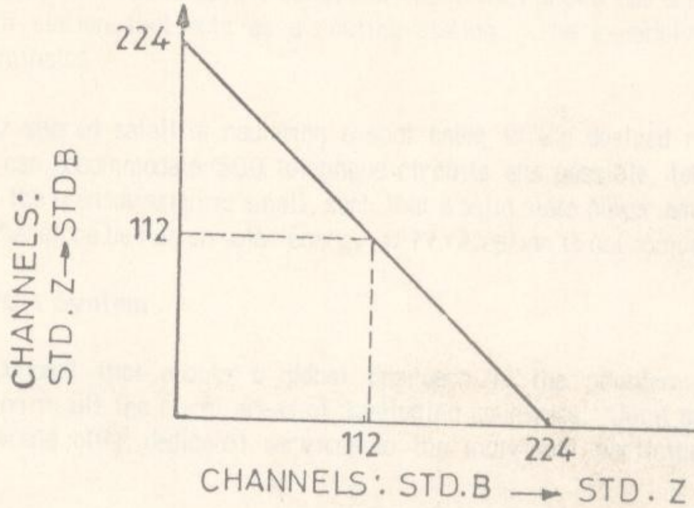

Fig. 3 : Transponder channel capacity of double level SCPC between standard Z and standard B earth stations.

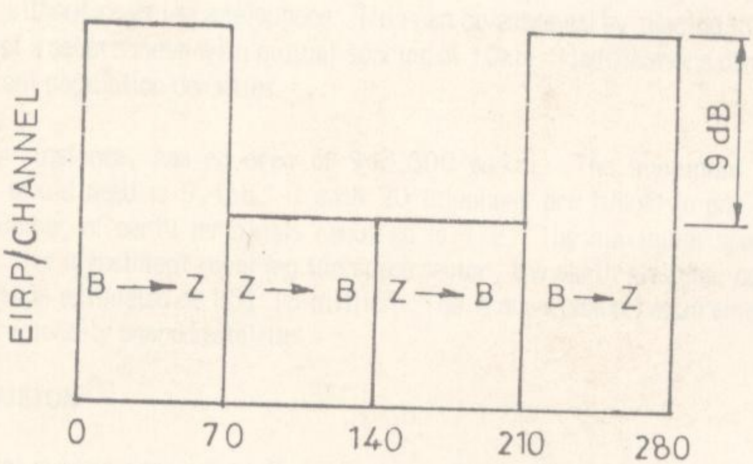

Fig. 4 : Transponder channel assignment for low intermodulation distortion.

3.2 A Regionally Shared Satellite

A regional satellite for domestic application in Africa has been proposed in (3) and (8). The objective of this satellite is to carry interstate liason and national missions. The satellite will handle telephone, telex, facsmile, radio and TV exchanges between states and extend these services to both the rural and urban areas at national levels. The interstate communication will be facilitated through an African zonal beam, with domestic mission through spot beams. For rural communication all the standard-z earth stations in the rural areas are linked to a common standard-z earth station that acts as a routing station. The expensive SPADE switching equipment is eliminated.

For a regionally shared satellite radiating a spot beam to the desired region, up to 1000 carriers which can accommodate 500 telephone circuits are possible, table III. The power requirement for the transmission is small, such that a solid state power amplifier can be used. The station can therefore be run on solar energy, if TV reception is not included.

3.3 The GLODOM System

GLODOM is a concept that adopts a global approach to the problem of domestic rural telecommunication in all the rural areas of developing countries. Joint ownership of all the satellites that would offer dedicated services to the individual participating countries are proposed in (4).

The space segment would consist of 4 satellites, each serving a regional group; America, South and East Asia, the South Pacific and some parts of Asia. Each satellite would have a capacity of 24 transponders and each transponder a capacity of 500 telephone channels. If each channel serves one ground station, and each ground station can collect traffic from 20 rural subscribers then a total of 960,000 telephone accesses can be achieved. The attraction of such a system is that through shared ownership of the space-segment by many participants and due to the economy of mass production the cost per line could be 5 times lower than the current cost per line of establishing a terrestrial link.

The siting of the access points would be such that no person has to walk for more than 7km (one hour walk) without reaching a telephone. This can be achieved by placing the access telephones at the nodes of a square mesh with mutual spacing of 10km. Modifications can be made depending on the different population densities.

Tanzania, for instance, has an area of 943,800 sq.km. The maximum number of access telephone it would need is 9,438. If each 20 telephone are linked to one ground station the maximum number of earth terminals required is 472. The maximum space required is one transponder. Its investment covering the space sector, the earth stations, connecting lines and telephone sets is estimated at US$ 15 million. The transmission requirements are similar to those of the regionally shared satellite.

4.0 CONCLUSION

The significant system parameters that determine the system performance and investment cost can be obtained from link budget tables. In the leased INTELSAT system the transponder power is lower. This necessitates the use of FEC coding scheme and communication to a common standard B earth station for higher capacity. The high power amplifier (HPA) at the rural earth station requires more power. Both these factors contribute to a higher ground station cost and more investment to the leaser. On the other hand a Regionally shared satellite and the GLODOM system require only lower cost earth stations. In their case the space segment demands more power and therefore more investment. Extra investment in the space segment is more attractive, since this reduces overall ground station investment especially because many of them are needed.

The difference between the GLODOM system and the Regionally Shared Satellite system mainly lies in the extent of mass production and shared ownership of the satellites, which lower the investment and running cost per participating nation. For a Regionally shared satellite system, Africa would require one satellite in space and one a ground spare. In the GLODOM system one satellite is allocated to Africa. The total investment in the latter case is lower since it is spread over 5 satellites, 4 in space and 1 a ground spare, and many more nations could participate. The difficulty in the GLODOM system would be to get the different countries with different priorities to participate.

5.0 REFERENCES

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6.0 ACKNOWLEDGEMENTS

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Table 1: TRANSPONDER PARAMETERS OF INTELSAT V AND V-A

Transponder Parameter	INTELSAT V Nos F1-F4	INTELSAT V Nos F5-F9	UNITS
SATURATION FLUX DENSITY			
Extra high gain	-82.5	-85.1	dB/m
High gain	-75.0	-77.0	dB/m
Low gain	- 67.5	-70.0	dB/m
G/T	-18.6	-16.0	dB/K
EIRP	23.5	23.5	dBW

Table 2: LINK POWER BUDGET USING INTELSAT V TRANSPONDER

	TRANSMISSION	DIRECTION	UNITS
	STANDARD - Z TO STANDARD -B	STANDARD-B TO STANDARD-Z	
I UPLINK			
1. Saturation powerflux density	-82.5	82.5	dBW/m
2. Antenna gain 1m	37.0	37.0	dB
3. Input back off	4.0	4.0	dB
4. Usable power at satellite	-123.5	-123.5	dBW
5. (G/T) SAR,= 10	-18.6	18.6	dB/K
6: (C/T) up	142.1	142.1	dBW/K
7. Boltzmann's constant	228.6	-228.6	dBW/K-Hz
8. (C/No) up	86.5	86.5	dB
9. ASI + RF OBE	5.0		
10. (C/No) up available	81.15	81.15	dB-Hz
II TRANSPONDER INTER-MODULATION (BO = 2.5 dB)	87.9	87.9	dB-Hz

	TRANSMISSION	DIRECTION	UNITS
	STANDARD-Z TO STANDARD-B	STANDARD-B TO STANDARD-Z	
III DOWNLINK			
1. Satruration EIRP	14.5	23.5	dBW
2. Output backoff	2.5	2.5	dB
3. EIRP beam edge	12.0	21.0	dBW
4. Downlink path loss on clear sky	196.2	196.2	dB
5. Pointing Loss	1.0	1.0	dB
6. Usable power at earth station	-185.2	-176.2	dBW
7. Earth station G/T	31.7	22.7	dB/K
8. C/T DN	-153.5	-153.5	dBW/K
9. Boltzmanns const.	-228.6	-228.6	dBW/K-Hz
10. C/No DN	75.1	75.1	dB-Hz
IV CAPACITY			
1. C/No TOTAL	74.0	74.0	dB-Hz
2. C/No required	50.5	50.5	dB-Hz
3. Number of carriers (dB)	23.5	28.5	dB
4. Number of carriers(numeric)	224	224	carriers
5. Number of carrier with voice (activity factor p=0.4)	560	560	carriers
6. Maximum number of two-level carriers in each direction	280	280	carriers
V EARTH STATION			
1. Usable power at satellite	-123.5	123.5	dBW
2. Uplink path loss	199.7	199.7	dB
3. Pointing loss	1.5	1.5	dB
4. EIRP at earth station	77.7	77.7	dBW
5. Number of carriers	24.5	24.5	dB
6. EIRP/carrier	53.2	53.2	dBW
7.. EIRP/carruer + dB margin	54.2	54.2	dBW
8. Antenna gain	47.4	54.2	dB
9. Feed system loss	1.0	1.0	dB
10. HPA	7.8	1.0	dBW

Table 3: LINK POWER BUDGET FOR A REGIONAL SHARED SATELLITE

I UPLINK		
1. Saturation power flux density	-80.0	dBW/m
2. Antenna gain for 1 sq m	37.0	dB
3. Input backoff BOi	4.0	dB
4. Usable power at satellite	-121.0	dBW
5. G/T sat, 10	-3.0	dB/K
6. C/T up	124.0	dBW/K
7. Boltzmann's constant	228.6	dBW/K-Hz
8. C/No up	104.6	dB-Hz
9. ASI+RF OBE	5.0	dB
10. C/No up available	99.6	dB-Hz
II TRANSPONDER INTERMODULATION		
with 1.0 dB backoff C/No im	87.9	dB-Hz
III DOWNLINK		
1. Saturation EIRP	33.0	dBW
2. Output backoff BOo	1.0	dB
3. Free space path loss on clear sky	196.7	dB
4. Pointing loss	1.0	dB
5. Usable power at earth station	-165.7	dBW
6. Earth station G/T	22.7	dB/K
7. C/T dn	-143.0	dBW/K
8. Boltzmann's constant	-228.6	dBW/K-Hz
9. C/No DN	85.6	dB-Hz
IV CAPACITY		
1. C/No total	83.5	dB-Hz
2. C/No required	53.5	dB-Hz
3. Number of channels (dB)	30.0	dB
4. Number of channels (numeric)	1000	Channels

V EARTH STATION

1. Usable power at satellite	-121.0	dBW
2. Uplink path loss	199.7	dB
3. Pointing loss	1.0	dB
4. EIRP	79.7	dBW
5. Number of carriers	30.0	dB
6. EIRP/carrier	49.7	dBW
7. EIRP/carrier + dB margin	50.7	dBW
8. Antenna gain 5m, 55% eff.	47.4	dB
9. Feed system loss	1.0	dB
10. HPA	4.0	dBW