Utilization of Ka-Band in Saudi Arabia[*]

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Abstract

This paper surveys the potential use of new Ka-band satellite systems. The market trends are presented and constraints are discussed. Utilization of Ka-band VSAT and LEO satellite in the Kingdome of Saudi Arabia is given. It is found that Ka-band utilization in KSA is promising asset for commercial and military multimedia applications due to the arid climate of the region.

I. Introduction

The term Ka-band system is not just operating at higher frequencies. It is recognised as a shorthand term for a new generation of communications satellites that encompasses a number of innovative technologies such as on-board processing (OBP) for multimedia applications [1] ,and switching to provide full two way services to and from small ground terminals [2]. To do this efficiently multiple pencils like spot beams are used. A number of proposals also include use of inter-satellite links [3] Apart from the conventional geo-stationary orbit; both low ground and middle ground orbit systems have been planned [4].

Ka-band satellite systems have also been described as "multimedia satellites", "ATM satellites", "broadband switched “, and”broadband interactive satellites". The first two terms are generally inaccurate in that Ka-band satellites can be used for other applications than multimedia or providing an ATM platform. The term "ATM Satellite" is also incorrect because on-board switching can involve either ATM switching or circuit switching or both.

Indeed, on-board processing and switching (effectively the provision of the equivalent of a sophisticated telephone switchboard on a satellite) are already employed in satellites providing mobile communications to hand held receivers. One of mobile satellite systems (Iridium) employed Ka-band communications for links between fixed ground stations (19.4-19.6 GHz downlink and 29.1-29.3 GHz uplink) that interconnect the public switched telephone networks to the satellites and 23.18 -23.38 GHz for inter-satellite links). However, the links between the satellites and the hand held receivers are in L-band (1616-1626.5 MHz) [5]. Worldwide, there have been considerable experimental Ka-band satellites such as ITALSAT(Italy), ACTS (US) , DFS (Germany) and Olympus (ESA) , as well as commercial communications systems, to solve the problem of saturation of the available orbital slots at C and Ku-band and to provide new services for the information age. Table (1) summarizes representative features of some major experimental and commercial Ka-band systems [6].

Table (1) summary of representative features of some major Ka-band systems.

System	**Coverage**	**Uplink/ Downlink (GHZ)**	**Throughput (Gbps)**	**Waveform**	**User Data Rate (Kbps)**	**Architecture/ Network Structure**
DFS-Kopernikus (Germany)	Regional/ GEO	29.58/ 19.78	Not Available	QPSK	64-2048	TDMA/18 m sec Frame Divided into 5 Segments

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ITALSAT Multibeam Global Payload (Italy)	Regional/ GEO	27.5-30/ 18.5-20.0	Several	QPSK	32-128	TDMA/32 msec Frame Divided into 3072 Frame Units
DRS (ESA)	Regional/ GEO	29.530/ 17.7-20.2	Several	QPSK	2 x500	Not Available
CS-2/CS-3 (Japan)	Regional/ GEO	27.515-28.995/ 17.775-19.195	Not Available	BPSK / FM	192-6144	TDMA,FDMA,DAMA
Astronik (US)	Global/ GEO	27.5-30/ 17.3-21.2	7.7	QPSK	16-9216	U/L: FDMA/TDMA, D/L:FDM; ATM,DAMA, OBP
Teledesic (US)	Global/ (LEO)1375 Km	28.6-29.1/ 18.8-19.3	13.3	QPSK	16-23000	U/L: FDMA/TDMA D/L:FDM; Satellite-Based Packet-Switched, OBP

Why Ka-band? In effect, the switching capability is making them operate like a public telephone network in the sky, but with the facility to offer digital services with a wide variety of bit rates. Users can be offered 'bit rate on demand' and its variation, 'variable bit rate on demand'. This contrasts with conventional satellites where users usually have to pay for permanent leases. That only makes it economic to use satellites where there is a massive amount of information to be moved, such as TV channels and trunk telephony links. The Ka-band environment also allows an alternative, charging per bit of information moved.

The prime method of using the available spectrum efficiently is to use multiple "pencil" spot beams, each covering only a small area of the ground. This allows frequency re-use in much the same way as a cellular phone network re-uses spectrum. Ka-band can service integrated Ku-band/Ka-band receivers to provide consumers with a combination of one-way broadcast and two-way interactive offerings. In the consumer environment, the stand-alone Ka-band terminals, without DBS TV capabilities, are much more likely to serve a mass market.

Other potential markets of Ka-band include the emerging Voice over IP (VoIP) [7], tele-medicine, tele-education, voice, local television, VSATs, "home-use VSATs", satellite newsgathering, and military intelligence.

The experimental ITALSAT and ACTS satellites have demonstrated the usefulness of Ka-band by including novel services such as: digital communications, on demand rain compensation, hopping spot-beams, on-board switching, and integrated services [8]. For tactical applications, processed payloads have the advantages of reducing ground terminal cost. Use of Ka bandwidth with spread spectrum can provide adequate degree of jamming protection [9]. The commercial communication asset with global coverage with constellation of GEO and LEO operating at Ka-band has offered an attractive solution to deliver multimedia personal communication services (PCS)[1] in US military missions such as Desert Storm, Desert Watch [10], and Iraq invasion. The Iraq war proved how essential weather, communications and targeting satellites are to the U.S. military. The Pentagon would continue to build its own satellites for their national security and economic reasons, but 80 percent of its capacity during the Iraq war was provided by commercial satellite operators, and that trend would continue. The Iraqi war would be seen as the most integrated and precise military engagement in history, largely due to a greater use of space-based

[1] PCS allows "anywhere, any time" voice and data communications. It is a second-generation digital voice, messaging and data cell phone system in the 2GHz range. PCS is supported mostly by GSM. PCS systems use a different radio frequency (1.9 GHz band) than cellular phones and generally use all digital technology for transmission and reception. "Digital PCS" is a redundancy, as all PCS are digital, but the phrase is used in marketing to distinguish PCS from cellular.

equipment at Ka-band. This included satellites used to gather intelligence, transmit encrypted messages, identify targets and give early warning of sand storms. The reason US military units were able to network the force so effectively was because the command central and the major military units all had uplinks to communications satellites [11]. Over the next decade, top satellite makers like Boeing, Lockheed Martin and Northrop Grumman will vie for multibillion-dollar orders as the U.S. military upgrades or replaces nearly all its satellites.

Market: Lockheed sees military and commercial space sales expanding up to about $7.7 billion in 2003 and 2004 from $7.4 billion in 2002 [12]. In most cases transmission costs via satellite are likely to be significantly higher than those available where there is a reasonably sophisticated terrestrial infrastructure. Perhaps the one clear exception to this is in the provision of high speed Internet access where the main alternative currently remains as ISDN and where the satellite option looks to be cheaper than using high-speed cable modems. The use of geo-stationary satellites creates significant technical and commercial disadvantages where voice and two-way video are involved. This may rule out delivery of some services based on the ATM platform. Use of LEO and MEO satellite configurations involve substantial initial capital investments by the satellite operators in contrast to the GEO option. GEO requires only a single Ka-band payload on a single satellite before service can start, and investment can be scaled up when demand increases. Typically the GEO environment may require initial investment (and therefore market exposure) of the order of hundreds million of US$ whereas the LEO or MEO environment involves initial exposure well in excess of $1 billion.

The OBP payload - that contains on-board demodulators, base band switch and demodulators – is relatively heavy and represents a major challenge. It places a severe constraint on what else the satellite can carry of conventional communications equipment. The number of spot beams determine the mass and power consumption of the OBP payload for a given coverage and throughput. Advanced packaging techniques are required to minimize mass and volume [1]. In the engineering trade-offs needed to accommodate the OBP payload this may include reduction of station keeping fuel or increasing the mass of the satellite with associated increases in platform and launch costs. The R&D establishment continues to work on developing lower mass OBP equipment. Recently on February 2004, ALCATEL ESPACIO introduced AMERHIS OBP, supported and co-funded by ESA and Industry, to deploy an advanced communications system based on a regenerative payload on board the AMAZONAS satellite. The AMERHIS system will support IP services as well as native MPEG based services with efficient multicast and QoS support. Interconnection with terrestrial networks (ISDN, PSTN, Internet, etc.) is also supported through gateways. The on-board budgets (4 channels**)** are**:** 216Mbps total Processed Capacity: 210W power Consumption and 29.5Kg [13]. Over the long term, telecommunication market is growing because of international trade growth and reduced prices of IT services. Broadband services and private VSAT depends on bringing down the cost of user terminal [14].

II. Propagation Impairments

The abilities of Ka-band systems come with some problems attached. First Ka-band signals are severely attenuated by rain. NASA's rain rate measurements at different eight sites in USA indicated larger fades probabilities than any other ACTS site, Table (2).

Site	Attenuation (dB) exceeded 0.1% of time	Frequency (GHz)	Elevation (degrees)	Reference
Tampa, Florida	30	20	52	[15]

Humacao, Puerto Rico	24 (AFS[2])	20.7	37.2	[16]

Figure (1) shows the result of ITALSAT propagation experiment in Italy for frequency bands 20, 40 and 50 GHz [17], where the effect of frequency increase on rain attenuation is evident.

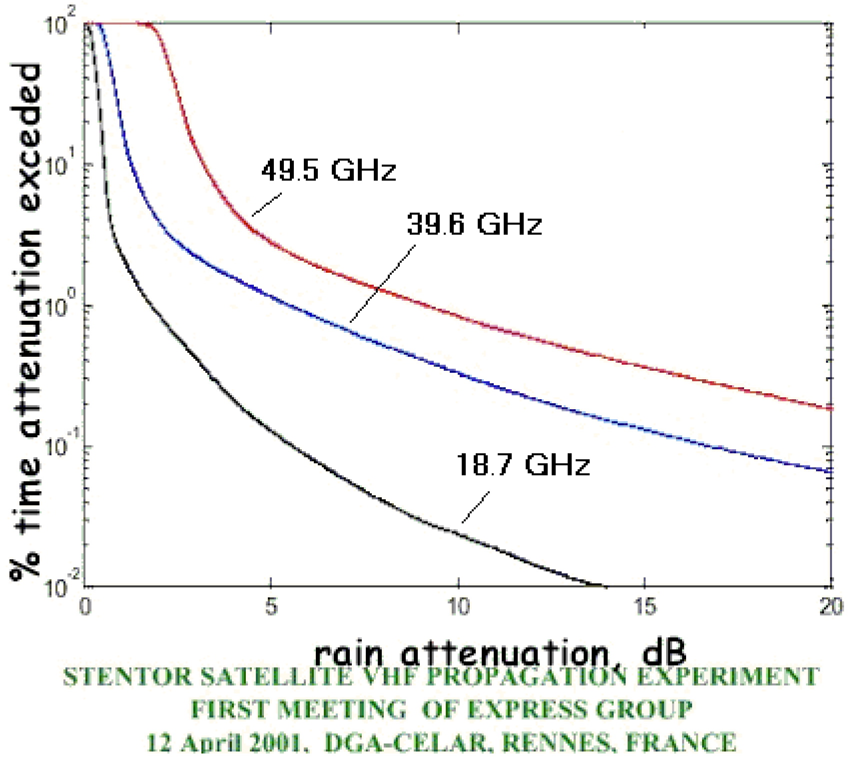

Figure 1 ITALSAT Yearly Statistics, 2001

The commutative four years distribution at 20 and 27 GHz from New Mexico ACTS terminal receives 99.9% AFS availability margins for 20.2 and 27.5 GHz are 5.4 and 8.4 dB respectively. It was found that wet antenna effect should be included in the link budget [18]. The second problem is limited coverage due to rain losses. Number of focused spot beams allows them to cut through rain, but at the cost of more EIRP and more cost. That is why vendors are talking about 99.5% availability for Ka-band as opposed to the more than 99.9% availability with the C- and Ku-bands.

Effect of rain on the Ka-band Land Mobile Satellite Channel (LMSC) using the ACTS shows that rain attenuation at 27 GHz is more severe than at 20 GHz. Envelope distribution is Gaussian, and mean and variance of power attenuation increase with rain rate increase. It was found that the SNR difference to get a BER of 10^{-4} between a heavy rain and clear sky case is 3- 9 dB for 20 GHz signal. For 27 GHz signal the SNR difference is 11-18 dB [19].

III. Ka-Band in KSA

To the best of author's knowledge, there are no experimental studies on the utilization of Ka-band in the Kingdom of Saudi Arabia. However, an assessment of rain attenuation on VSAT satellite link availability at Ku- and Ka-bands has been studied by one of the authors [20]. It was found that satellite links operating at Ku- or Ka band are affected by rain attenuation in terms of degradation in link reliability. In particular, the rain attenuation has

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[2] AFS: attenuation relative to free space that is composed of gaseous attenuation, clear air attenuation, clouds, scintillation, and antenna wetting factor.

been calculated as a function of space link availability and elevation angle as well as G/T margin due to noise temperature increase. The main findings can be summarized as follows:

(i) As shown in Figure (2), it is clear that the CCIR A and C zones underestimate zones #1 and #2 of the locally developed rain rate map[21]. Moreover, the southwestern part has more rain rates than what has been projected by the CCIR. However, most rain rate in Saudi Arabia is less than that of North America or Europe.

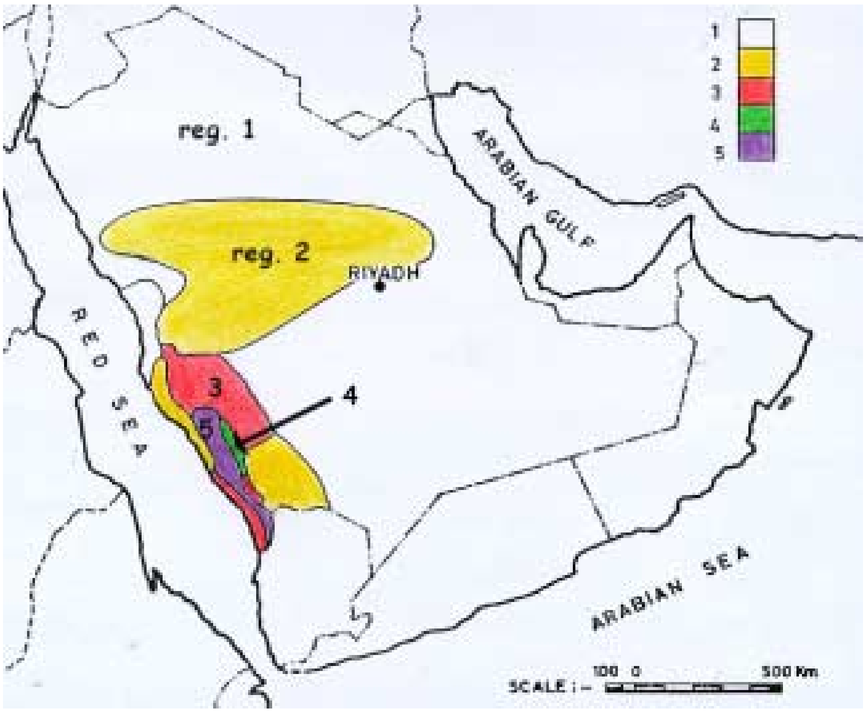

Figure 2a measured rain rate regions in KSA[21].

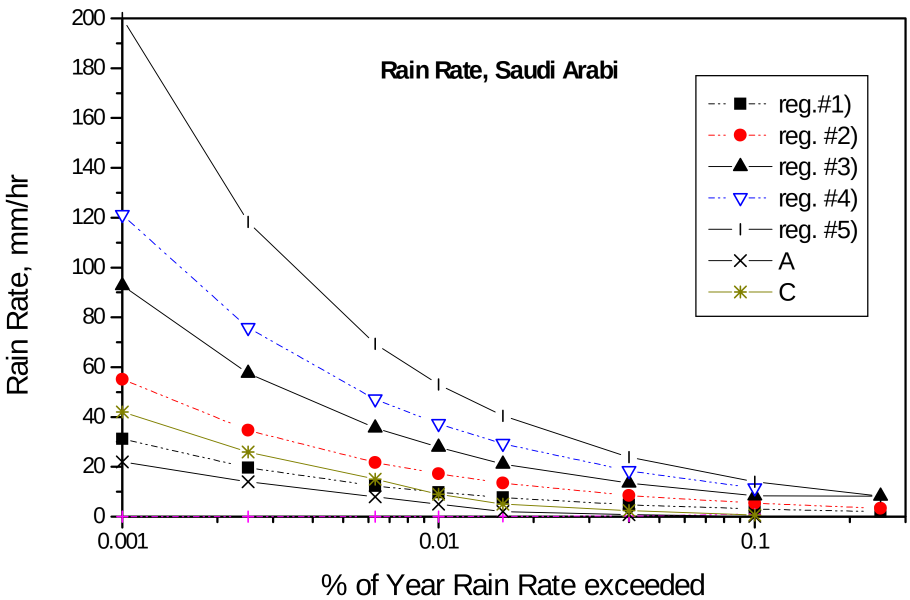

Figure 2 b: Rain Rate distribution in Saudi Arabia, measured viz. CCIR data.

(ii) For system availability of 99.8% and for an elevation angle θ = 10°, the total margin for Ka-band may vary from about 4.7-18 dB t depending on the rain climatic zones. The margins decrease to about 1.7-9 dB for higher values of θ = 50°. For ku-band, the respective values vary from about 2.34 dB and 9 dB. The margins decrease to about 1 dB to 5 dB for higher values of θ = 50°.

(iii) For the same system conditions, the total margin for region #5 in KSA is comparable with region D3 in USA, yet fewer margins (about 2.3 dB) is sufficient in the majority of KSA (region #1 and #2).

(v) The total margins of the down link and G/T degradation are lower for regions #1 and #2 compared with the south-western regions. This leads to the possibility of operating a VSAT system at higher system availability (99.9%) and at moderate values of elevation angles. However, operating at higher elevation angle (e.g. 50° as for ARABSAT) will not require high rain margin in the majority of the country (about 2.3 dB for Ku-band in region #1).

(vi) If lower link availability of about 99% is to be achieved for VSAT in region #5 , total margins as low as 3.7 dB and 1.9 dB are sufficient at Ku-band for elevations 10^o to 50^o respectively. The respective values are 6.9 dB and 3.8 dB at Ka-band. Generally, the total margins are less than 1.5 dB and 2.8 dB for Ku- and Ka-bands respectively.

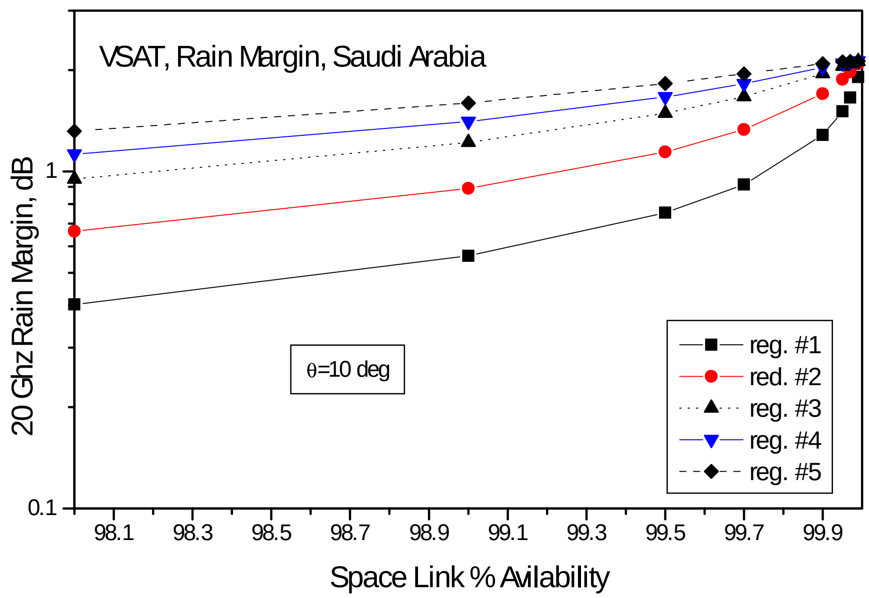

Figure (3) Rain Margin at 20 GHz versus link availability, θ= 10^o (using rain-map developed by ref.[21].

Figure (3) shows the rain margin versus link availability for VSAT in Saudi Arabia. In Ka-band, rain does not only cause attenuation, but also gives rise to noise, which further increase attenuation. Figure (4) shows the effect of the additional system noise temperature. The overall system availability is comprised of the space link availability (including noise effect) and the ground station availability (assumed 99.9% in our case). A prediction method to calculate the time variation of the elevation angle for a LEO satellite that requires the knowledge of its constellation parameters has been proposed by the authors [22]. As an example, a study of the rain attenuation on LEO satellite links at Ka-band working in different regions of Saudi Arabia revealed that the percent of time at which this satellite is visible over Riyadh region can be represented either by a simple power relation or by an exponential function, Figure (5). Using an approximated rain map developed by reference[23], it was found also that installing Ka-band gateways at the southeast region is not recommended because of relatively highest rain fade.. For the same margin, higher availability could be achieved in North or Central region. For system availability of 99% in Riyadh region, rain margin as low as 9 dB is sufficient. The respective value is 20 dB for higher rain rate climatic regions, Figure (6).

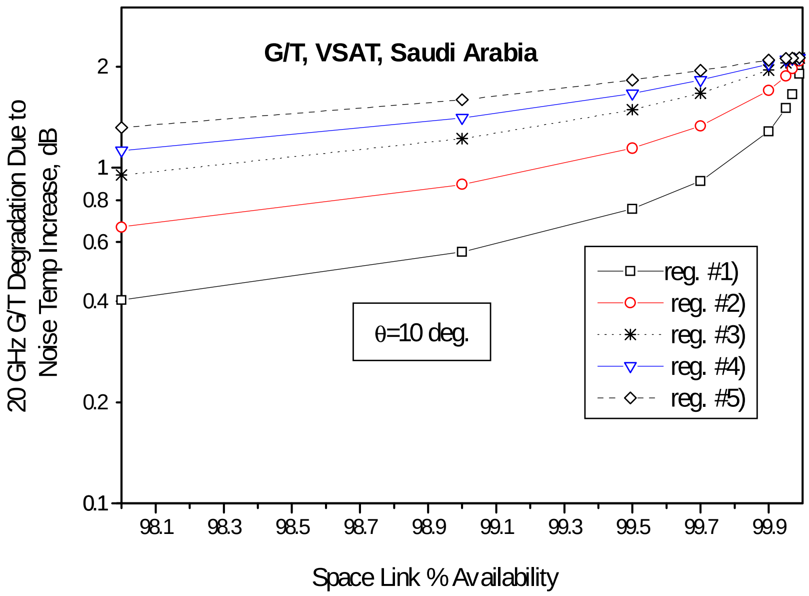

Figure (4) 20 GHz G/T Ddegeadation due Noise Temperature increase, VSAT, θ= 10^o.

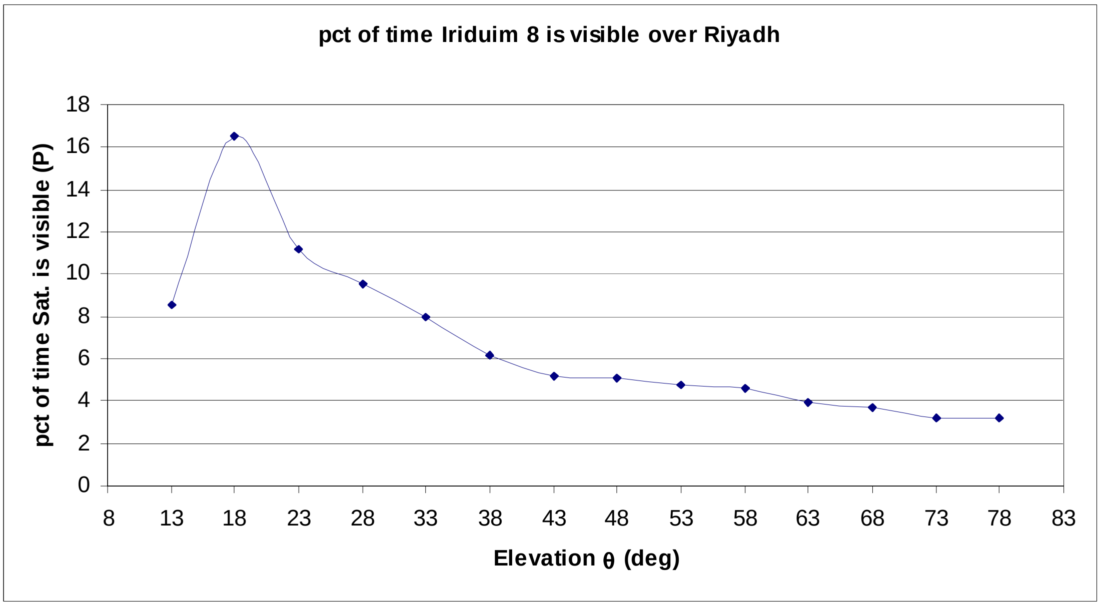

Figure (5) pct of time Iridium is visible over Riyadh

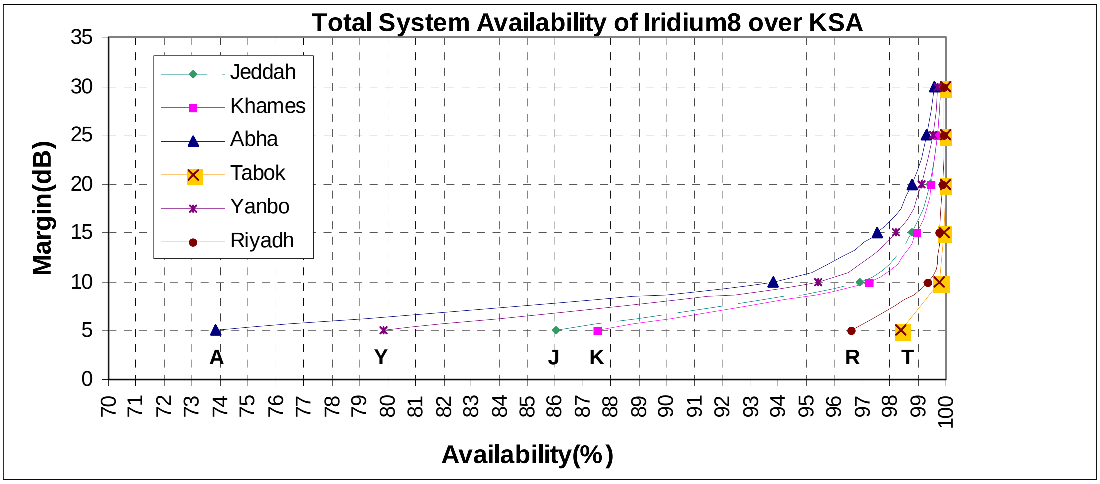

Figure (6) Total System Availability of Iridium#8 over Saudi Arabia (using rain-map developed by ref.[23].

The authors have also investigated the combined effects of atmospheric gases, rain, cloud and dust on LEO link operating at Ka band as a function of elevation angle in the Kingdom of Saudi Arabia. It was found that attenuation due to rain is still the dominant source of propagation impairment in Saudi Arabia (about 78% at 8^o elevation and p=0.01%), while dust effect contributes the minimum (less than 0.2%). However the sum of all other sources other than rain could be neglected (about 32%) [24].

IV. Conclusions

Ka-Band (20/30 GHz) can be used in the KSA for VSAT and mobile communication systems with system availability better than North America or Europe. Applications may include multimedia, VoIP, tele-medicine, tele-education, voice, local television, VSATs, "home-use VSATs”, satellite newsgathering, and military intelligence. Future measurements are required to confirm calculated results and rain map of KSA.

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