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Multibeam Contiguous Coverage for Domestic Satellite Services for Saudi Arabia

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ABSTRACT. A multibeam satellite reflector antenna to provide contiguous multibeam coverage of Saudi Arabia is analized. The satellite utilizes 12 beams each of 1^{O} cell size. Three overlapping beams were formed, which comply with the ITU requirements. Composite coverage patterns are computed, projected on a map.

Several regional and domestic satellite communication system are being planned for the next few years. In special terms we mention efforts being made by India, Australia, Latin American and Arabic countries, as examples of performing needful services for developing nations by space utilization. For developed countries, space technology has become a crucial aspect of industrial expansion and every day activities, including the military services. For developing countries, satellite communications is a way to leapfrog the costly slow development of telecommunications using cables and microwave networks between widely spread regions. Examples of special services otherwise are unaffordable use of remote sensing satellites which provide information about the country sides that no other method can give. Fast and efficient scans for correct resource mapping are becoming mainly dependent on satellites. Satellites are also extremely effective in the provision of inexpensive television reception in remote areas (Guterl 1983).

Proposed Satellite for Saudi Arabia

New plans are proposed in this paper for the Kingdom of Saudi Arabia (K.S.A.) to have a domestic satellite system at Ku-band frequencies, known as the Domestic Satellite for Saudi Arabia or DSSA. This would provide, initially, direct

television, broadcasting and other services using the eleven channels assigned by the International Telecommunication Union (ITU) in three major overlapping beams. These beams were specified by the World Administrative Radio Conference (WARC), Geneva, 1977 and are shown in Fig. 1.

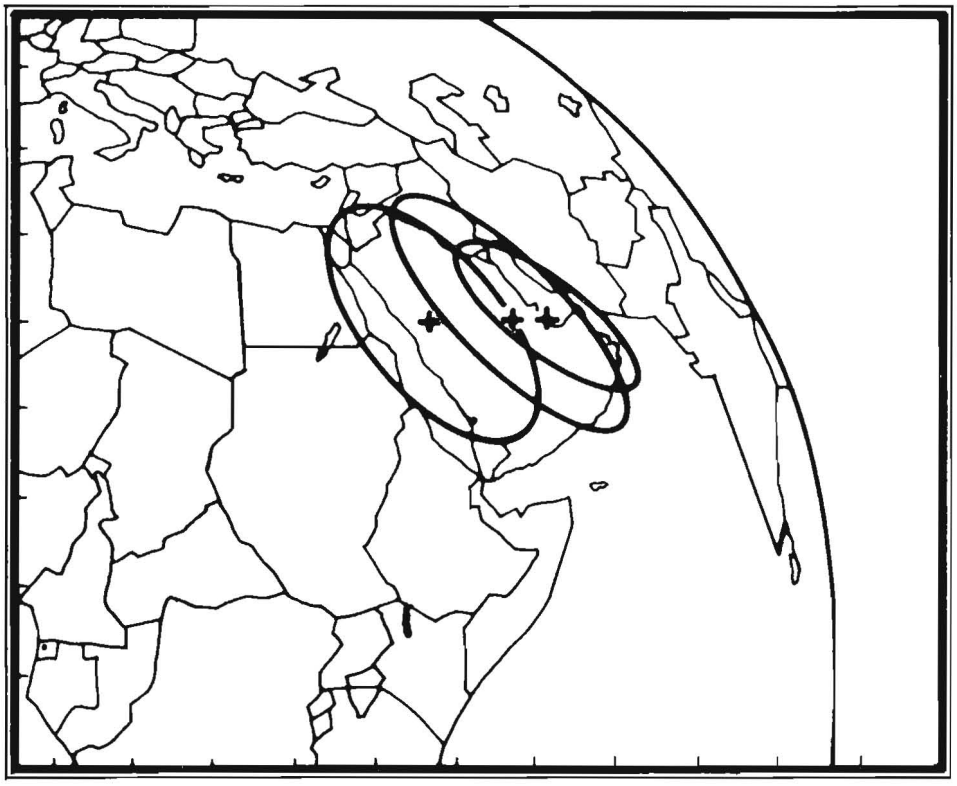


Fig. 1. Project map with I.T.U. coverage beams (17° longitude east)

Two of the beams overlap to cover the eastern and western parts of the country and the third beam covers the gulf region (Final acts of WARC 1977). The broadcast and telecommunication services may be allocated on a priority basis in accordance with the needs of different sectors. Major services may be classified as follows:

a) Broadcasting networking, including T.V. programmes and radio broadcasting (AM and FM stations). This also includes special local community programs.

b) Community services for T.V. programs and radio programs as well as special agricultural, medical, commercial entertainment and conferencing services.

c) Data transmission, computer networking, telephone services, including mobile connections, especially off shore activities as well as military and national security and intelligence needs.

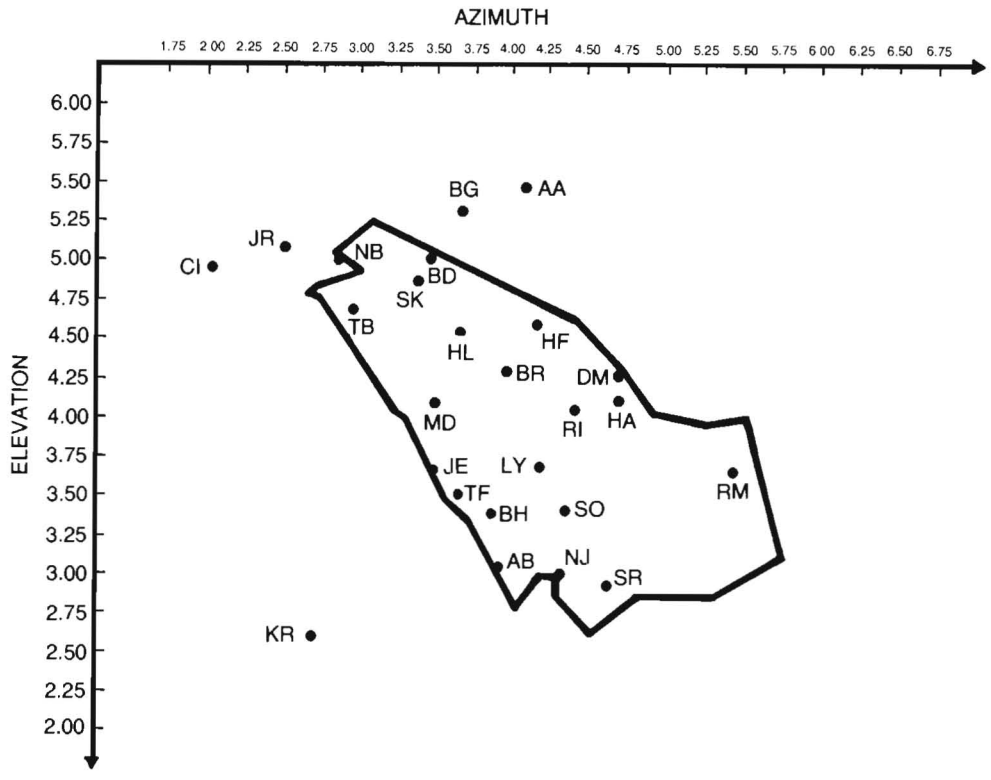
d) Possible future arrangements to network with international communities using an intersatellite link.

One antenna could perform both the transmit and receive functions to earth; such designs have been applied to the Japanese Broadcast Experimental Satellite (BSE) launched successfully in 1977, and also to the Communication Technology Satellite (CTS) launched by U.S.A. and Canada for a Ku-band experiment with a 200-TWT. Similar designs are used in this design of the DSSA. In this case, the down link antenna performs also the up-link functions. The uplink function is not necessarily applicable to each beam and hence one of the beams might be used to perform as uplink for all the others.

Multibeam Antenna Design

The handling of multiple contiguous beams by one antenna would cover the whole country and yet add the advantages of multibeam contiguous coverage. The multiple beams are arranged in a continuous cluster with cross-over level between the beams at the -6 dB level, which proved optimum for the beam and its edge grains. It provides also optimum flatness for the contiguous coverage (Afifi 1984).

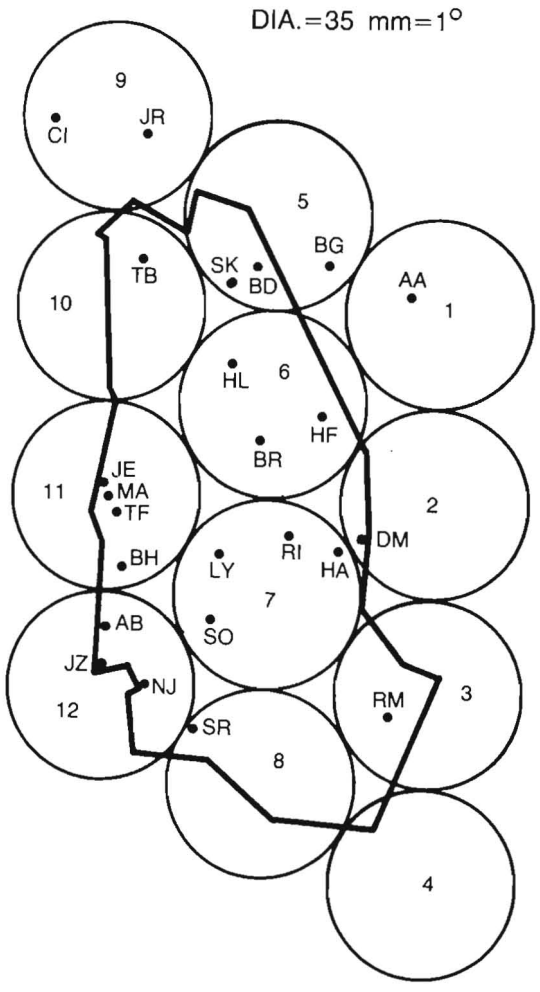
Projections are made of the K.S.A. map as seen from the satellite, including main cities inside the country and a few cities outside the country. Many points, at the borders of the country are used to project its map, in terms of satellite look angles, using a computer program. The program outputs are azimuth and elevation for each map point as viewed from the satellite. These are shown in the satellite projections of Fig. 2. There are twelve contiguous beam cells, as shown projected on the country map in Fig. 3. Note that three beams are the minimum required in order to verify the overlap between beams 1 and 2 of the ITU coverage. One degree cell diameter is used for each beam cell. These three one-degree cells across the country would allow extra room for the edge cell gain to drop to the optimum 6 dB value beyond the borders of the country, so that the borders are covered by approximately the −4 dB levels. Manipulations proved that one degree beams are the suitable choice to realize this condition (Alnasser 1984).



Explanation

CI	=	Cairo	TB	=	Tabuk	SR	=	Sharurah
JR	=	Jerusalem	HL	=	Hail	SO	=	Al Sulayy'l
BG	=	Baghdad	HF	=	Al-Hafr	LY	=	Layla
AA	=	Tehran	BR	=	Buraidah	RI	=	Riyadh
KR	=	Khartoum	MD	=	Medinah	DM	=	Dammam
NB	=	Al-Nabk	JE	=	Jeddah	HA	=	Hafuf
BD	=	Badanah	TF	=	Taif	RM	=	Ramlah
SK	=	Skaka	BH	=	Al Bahah			
AB	=	Abha	NJ	=	Najran			

Fig. 2. Project map in the satellite field of view



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AA	= Tehran	HF	= Al-Hafr	RM	= Ramlah
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BG	= Baghdad	JR	= Jerusalem	SR	= Sharurah
BH	= Al Bahah	JZ	= Jizan	TB	= Tabuk
BR	= Buraidah	LY	= Layla	TF	Taif
CI	= Cairo	MA	= Makka		
DM	= Dammam	NJ	= Najran		
HA	= Hafuf	RI	= Riyadh		

Fig. 3. The twelve beams projections on the Kingdom map

The radiation beam analysis used the circular aperture approximation for the antenna performance. Circular symmetry for the secondary pattern is assumed associated with the feed-reflector combined distribution. For special interest the considered distribution has the form (Silver 1949):

$$f(r) = (1-A) + (1-r^2)^2$$

where $f(r)$ is the normalized aperture distribution, (1-A) is the relative illumination from the feed at the edge of the reflector, related to the field at its centre (which is given by unity), and r is the normalized radius = ρ/a, where a is the radius of the aperture and ρ is a polar aperture coordinate. The gain pattern of the antenna using this function is given by:

$$G = 2\pi a^2 \int_0^1 f(r) j_0(ur) r dr$$

$$= 2\pi a^2 \left[(1\text{-}A) \frac{J_1(u)}{u} + 4A \frac{J_3(u)}{u}\right]$$

where $J_0^n(ur)$ is the Bessel function of order n.

These equations are linearly transformed, added vectorially for different beams and programed to calculate the contiguous coverage from any number of clustered feeds in the focal area. The data input are assigned by the power level and phase excitation of each beam. Note, that the last equation is used by the program as an approximation for the real aperture distribution of the radiating antenna to calculate the individual patterns of different beams and to add these at their specific angles.

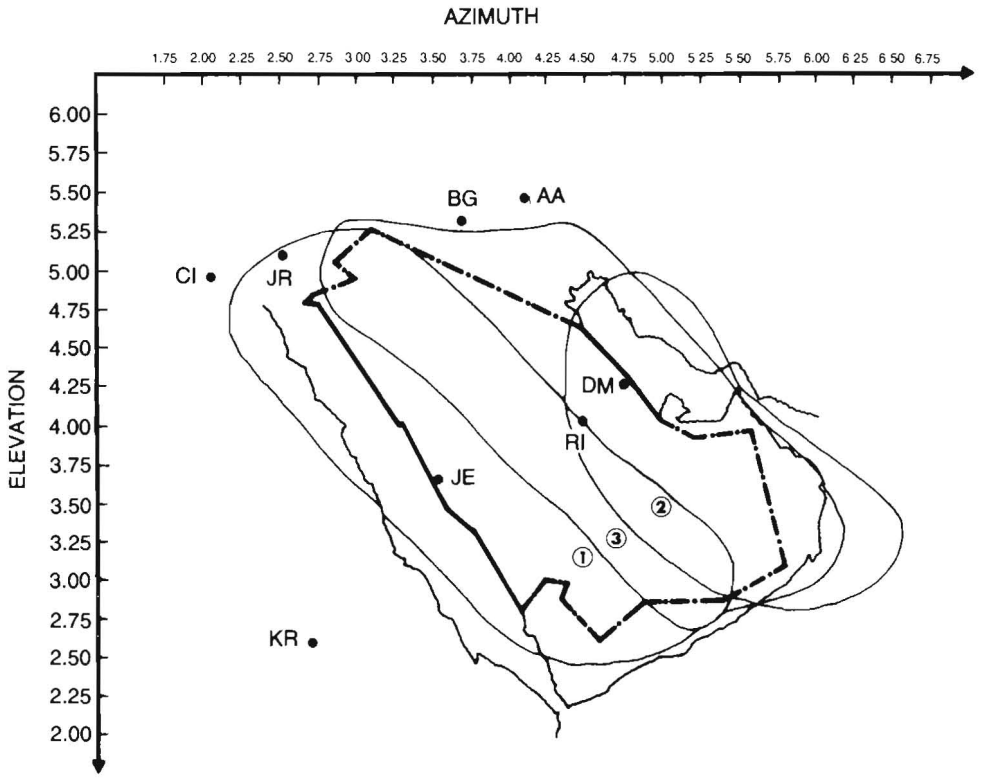
Concerning the antenna structure, many manufacturing established techniques are available. Kevlar for example is used on BSE (the Experimental Japanese Broadcast Satellite), Aluminium is also used, and recent technologies employ Graphite designs for light weight and structural stability reasons.

The Resultant Coverage Beams

A multibeam radiation pattern computer program using the previous formulation is used. The eastern and western beams use eight feeds each. The gulf beam, however, uses five feeds. These three contiguous beams are shown as projected on the country map for the downlink (12.1 GHZ) in Fig. 4, for the contour levels of 35 dBi (for the eastern and western beams) and 37 dBi (for the gulf beam). This coverage conforms more with the borders of the country and approximates to the ITU coverage ellipses. An example of the detailed coverage for the eastern beam is shown in Fig. 5. The main coverage beams are left handed

circularly polarized. It uses one antenna of circular aperture, with an aperture size of 74.5 inches. No blockage is considered and consequently an offset reflector configuration would be adequate (see Alnasser 1984).

This method is a fast design tool using an inexpensive approach to design the system initially. Later accurate computations may finalize the contour patterns and produce the depolarization performance. It also demonstrates the powerful tool of using the multibeam concept for contiguous coverage of multipurpose domestic systems.



CI	=	Cairo	DM	=	Dammam
JR	=	Jerusalem	RI	=	Riyadh
BG	=	Baghdad	JE	=	Jeddah
AA	=	Tehran	KR	=	Khartoum

Fig. 4. Coverage contours for DSSA

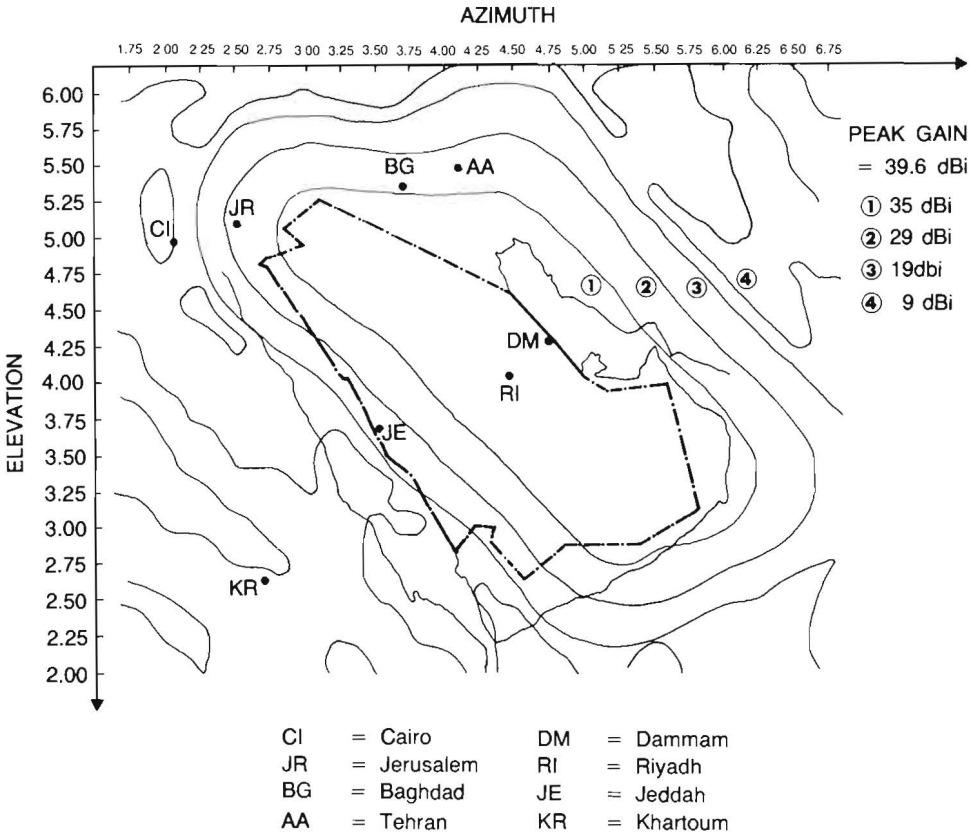


Fig. 5. An example of detailed coverage of the eastern beam (Frequency 12.1 GHZ, 8 composite beams)

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عنى هذا البحث بتصميم هوائي متعدد الأشعة ـ بوساطة الحاسب الآلي ـ يحمله قمر صناعي سعودي مقترح لتحقيق بث تلفزيوني وهاتفي شامل للمملكة.

وتتلخص الطريقة في استخدام إثنى عشر شعاع متجانس صغير ـ قطر الواحد منها درجة واحدة ـ لتغطية جميع أجزاء المملكة، وقد تم مع ذلك تكوين ثلاثة إشعاعات متلاحمة رئيسة ـ غطت المملكة العربية السعودية، ومنطقة الخليج تغطية شاملة، أحدها للقسم الشرقي والأوسط من المملكة مع دول الخليج، والثاني للجزء الغربي والأوسط أيضاً من المملكة، كما غطى الثالث منطقة الخليج مع أجزاء من المنطقة الشرقية، وبذلك يتفق هذا التصميم مع ما حدده الاتحاد الدولي للاتصالات السلكية واللاسلكية للمملكة العربية السعودية.