World Applied Sciences Journal 24 (2): 207-212, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.24.02.1024

Migration for Fixed Satellite Station in C-Band from Measat 1 to Measat 3

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Submitted: May 18, 2013; **Accepted:** Jun 29, 2013; **Published:** Aug 5, 2013

Abstract: Migration of frequencies has become a necessity to accommodate higher number of user and applications for future technology advancement. In Malaysia, the migration of C-band to accommodate fixed satellite services (FSS) has been made by the Malaysian Communication and Multimedia Commissions (MCMC) by the migration from MEASAT 1 to MEASAT 3. The frequencies range assignment has changed from between 3700 MHz to 4200 MHz and 5925 MHz to 6425MHz; to the frequency range of between 3400MHz to 3700MHz and 6425MHz and 6725MHz; an expansion of 300MHz. At the same time, the number of transponder has also increased from 12 transponders to 24 transponders. With changes in frequency range and number of transponders, the Received Coverage Area (RCA) is also changed. This is because RCA is directly influence by changes in the minimum elevation angle caused by change in the satellite altitude. The deployment of new satellite also introduces an economic impact in relation of the environment at which the satellite is deployed because the interference on the signal will greatly influence the offered service. Satellite altitude for MEASAT 1 is lower than MEASAT 3; giving higher interference in MEASAT 3. At the same time, the minimum elevation angle of MEASAT 3 is higher than MEASAT 1 therefore resulting in lower coverage area. However, higher frequency means a lighter weight and smaller satellite with lower power that reduce the cost of MEASAT 3. In long run, MEASAT 3 is seen as an essential migration because of its flexibility in design, able to operate in both C-band and Ku-band, overcome the congestion in the current C-band and most importantly, MEASAT 3 will allow a wider coverage inside and outside of Malaysia's territory which could have a huge economic impact for Malaysia.

Key words: Migration · Elevation angle · Satellite altitude · Received coverage area

INTRODUCTION

The Malaysian Communication and Multimedia Commissions (MCMC) is responsible for the assignment of the frequency for fixed satellite services (FSS), communication, broadcasting and other purpose in Malaysia. In Malaysia, the bands of frequencies that are being used are C-band and Ku-band. The C-band is used in peninsular Malaysia, Sabah and Sarawak while Ku-band is mostly used in peninsular Malaysia and the territory outside Malaysia. Before 1988, the frequency range for C band for Fixed Satellite Service (FSS) is between 3700 MHz to 4200 MHz and 5925 MHz to 6425MHz [1]. However, with the approval given by the World Administrative Radio Conference, the frequency for C-band for FSS has been expanded by 300MHz to frequency range of 3400MHz to 3700MHz and 6425MHz and 6725MHz.

The MEASAT 1; launched on 13 January 1996 [2] cater for the band of frequency range between 3700 MHz to 4200 MHz and 5925 MHz to 6425MHz while the launched of MEASAT 3 in 12 December 2006 is allocated by MCMC with frequencies that will replace MEASAT 1 with the inclusion of the new frequency range for FSS in C-band. In this paper, priority is given to the migration of MEASAT 1 to MEASAT 3 for FSS in C-band because first; the foot print of this band covers most of the area in Malaysia [1]; therefore most application are able to use this band of frequency. Second; the effect of this migration may or may not affect the apparatus used by the

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operators. Third; MEASAT 1 is mainly used for C-band whereas MEASAT 3 provides 24 transponders for C-band and 24 transponders for Ku-band with 36MHz for over 15 years of service life. Forth, the frequency usage in C-band for MEASAT 1 is saturated and therefore the need for a new frequency allocation is crucial. Fixed Satellite Services (FSS); (according to the Radio Regulation (RR No. S1.21)) is a radio communication services between one or more satellite to any given earth station position on Earth's surface [3]. The earth station position may be a specified fixed point or any fixed point within a specified area. A space station located on board the satellites consisting mainly the satellite transponders and associated antennas is another FSS station. These two stations when communicating with each other while using the C-band; will used an uplink frequency of 6GHz and a downlink frequency of 4GHz. Uplink connection is between the transmitting station and the satellite while a downlink connection is between the satellite and the receiving station.

MATERIALS AND METHODS

The immediate effect of the migration of C-band from MEASAT 1 to MEASAT 3 is the Receiving Coverage Area (RCA) of FSS. MEASAT 1 and MEASAT 3 are using geostationary (GEO) satellite. RCA of the GEO satellite covers almost one third of the earth surface and it is govern by parameters such as the minimum elevation angle of receiver antenna based on the satellite altitude, the restriction in the visibility of angles close to the horizon line, environmental factors and economic concerns [4].

Satellite Altitude: GEO satellite is position at the geostationary orbit at the height of approximately 35 800 km in the circular orbit. Kepler law stated that the closer the satellite to the earth, the faster the spin orbit. As GEO satellite is position at a higher orbit, the satellite will goes slower. The time taken for a complete rotation of GEO around the earth is approximately 24 hours or one day.

The speed of the satellite in an orbit can be determined using Newton's law of gravity and law of motion along with centripetal acceleration. The centripetal force, $F_{centripetal}$ and the centrifugal force, $F_{centrifugal}$ on the satellite must be equal to each other based on Newton's first law of motion. Based on this relationship, the mass of the satellite will not influence the speed of GEO satellite.

Table 1: Orbital speed for various altitudes

Altitude (km)	Orbital Speed (km/s)
100	7.84
500 (LEO)	7.61
1500	7.11
3000	6.51
5000	5.91
8000 (MEO)	5.26
10000	4.93
30000	3.31
35800 (GEO)	3.07

Table 1 shows the orbital speed at different altitudes. The selected values for the altitude and speed of satellites being calculated is in circular orbits.

Since GEO is in a circular orbit and can be consider as a fixed satellite, the positioning of the satellite into this orbit is crucial. The launch of the rocket carrying the satellite is first position itself into the Geostationary Transfer Orbit (GTO) [5]. The rocket firing mechanism will then cause the satellite to sling shot into the desired orbit at a specific orbital speed.

In order to fix the satellite in an orbit, it can be achieved via two methods. First, equalization of the gravitational force by the centrifugal force of the satellite as it circulating the earth at a proper speed which will enable the satellite to maintains its position in the orbit. However, as the satellite moves away from earth, the gravitational force towards the satellite is getting weaker causing the centrifugal force needed to balance the gravity also decreasing.

Second, the satellite is design to constantly falling toward the center of the Earth while still maintaining a constant distance with reference to the earth. Due to the strength of earth gravitational force toward the satellite and the satellite speed, the movement of satellite is parallel to the earth's surface as the earth continually curves away from satellite. By constantly monitoring of the speed and rate of falling of the satellite towards earth, we can position the satellite at the desired orbit.

Minimum Elevation Angle of Receiver Antenna: Elevation angle is the horizontal angle of the earth surface to the center line of the satellite transmission beam. Theoretically, transmission beam reaches the horizon is visible in all directions to the satellite when an elevation angle is at zero degrees. However, at present this value is not achievable because of environmental factors such as objects blocking the signal transmission and atmospheric attenuation. So, there is a minimum elevation angle of earth stations [6]. The coverage angle where the earth surface is visible to a satellite can be measured by taking into account the minimum elevation angle.

Restrictions of Visibility in Angles Close to Horizon Line: The geostationary orbit offers two advantages over any other orbit which are full visibility at all time as the satellite remains above the horizon and during this entire time, the satellite remains at a fixed point. By taking full advantage of these factors, GEO satellite earth station is able to use fixed antennas that can be accomplish by adjusting the pointing angle and the antenna mount or antenna offset angle. Pointing angle of the satellite is defined as the position of the satellite in term of angle as it appears from the antenna and can be measured by either the elevation and azimuth system or the polar or also known as hour angle and declination a ngle system. The antenna mount is the mechanism used to support the antenna to ensure the correct pointing angles.

Environmental: Signal degradation in satellite communication with frequencies above 10 GHz is mainly cause by rain attenuation [7]. An appropriate Fade Mitigation Technique (FMT) must be adopted to reduce fading outage of communication links to ensure the operation of modern satellite systems are economically and technically feasible with realistic fade margin that will satisfy the channel availability and quality of service (QoS) specifications.

This is especially crucial for satellite systems operating at higher frequency of above 10 GHz at regions with heavy rainfall like Malaysia as the signal attenuation will occur simultaneous with other types of atmospheric interference [4].

FMTs can be classified into three major categories that are EIRP control techniques, adaptive transmission techniques and diversity protection schemes. The EIRP control techniques varying either the transmitted power or the antenna gain to compensate for the power losses due to propagation effects. Adaptive transmission techniques focus on modifying the methods used to process signals or signal transmitted by the nodes of a satellite network (earth stations, satellites) whenever the link quality is degraded. The different types of signal processing are available to more than one earth station on demand. Diversity protection schemes are countermeasures oriented against rain fades which saw them as the most efficient FMTs because it increased the satellite availability and performance by reducing the rain induced attenuation [8].

Economic Concerns: The operation of MEASAT 3 is subjected to the same risks as MEASAT 1 which includes frequency congestions, failure during launch, signal interferences that will jeopardize the availability of offered services, technology advancement making the technology used are no longer viable and the inability of the satellite to be operational. All these factors increased the risk of operating new satellite apart from fierce competition from other satellite operators that may affect demand for satellite services.

MEASAT runs a strong and well managed business where the growth of video neighborhood which is both video distribution and Direct-To-Home (DTH). There will highly demand for the market for C-band and Ku- band capacity in Asia now and over the next few years revolve around video distribution and DTH applications (both video and broadband data). As an example, MEASAT today supports the Astro DTH network in Malaysia. As the Asian economies become more mature and as a greater proportion of consumers' income are channeled into entertainment services. General growth in the number of video and data services being delivered to consumers. With satellites holding significant advantage over terrestrial delivery, this will drive growth in both the DTH as well the satellite video distribution services. MEASAT 3 has an ability to meet this highly demand.

RESULTS AND DISCUSSION

Satellite Altitude: The satellites in MEASAT 1 and MEASAT 3 deploy a geostationary satellite (GEO). Therefore, the link between satellites with respect to earth station can be written as:

$$d = \frac{(R_E + R_H)\sin\alpha}{\cos\theta} \tag{1}$$

where d is the distance between satellite and the earth station, R_E is the radius of earth which is equal to 6371 km, R_H is the satellite altitude (for GEO, R_H is 35800km), α is the space angle between the satellite and the earth station and θ is the satellite elevation angle. So, equation (1) can be rewrite as

$$d = \frac{(42171km)\sin\alpha}{\cos\theta} \tag{2}$$

The distance between satellite and the earth station can also be written as path length or range, R in meter as:

$$R = 42171\sqrt{1 - 0.295577x\cos\Phi\cos\delta} \tag{3}$$

where Θ is the latitude and ä is the longitude of the Earth station minus that of the satellite (e.g. the relative longitude).

Table 2: Location in Malaysia receiving transmission from MEASAT 3

Location	Latitude	Longitude	Range, R (km)
Kuala Lumpur	3.13°N	101.7°E	37456.15
Johor Bharu	1.48°N	103.73°E	41634.15
Kota Kinabalu	5.98°N	116.07°E	36797.78
Alor Setar	6.12°N	100.37°E	47109.14

Table 3: The elevation angle and distance of several locations in Malaysia using MEASAT 3 as calculated using satellite look angle calculator

Location	Latatitude (°N)	Longitude (°E)	θ°	d (km)
Kuala Lumpur	3.13	101.7	77.45	35958
Johor Bharu	1.48	103.73	77.43	35958
Kota Kinabalu	5.98	116.07	77.43	35958
Alor Setar	6.12	100.37	77.43	35958

Table 4: The elevation angle of several locations in Malaysia receiving transmission from MEASAT1

Location	Latitude (°N)	Longitude (°E)	Elevation angle, θ (°)
Kuala Lumpur	3.13	101.7	26.295
Johor Bharu	1.48	103.73	24.115
Kota Kinabalu	5.98	116.07	11.159
Alor Setar	6.12	100.37	27.515

Table 5: Comparison of satellite range for MEASAT 3

Location	Latatitude (°N)	Longitude (°E)	R (km)	d (km)
Kuala Lumpur	3.13	101.7	37456	35958
Johor Bharu	1.48	103.73	41634	35958
Kota Kinabalu	5.98	116.07	36797	35958
Alor Setar	6.12	100.37	47109	35958

Table 6: Parameters for Satellite Link Budget

Parameters	Unit	Values
Antenna Offset Angle	Degrees	27.3
Offset antenna tilt	Degrees	140.2
Uplink delay to satellite	ms	119.718
Total delay up/down-link same site	ms	239.436
True Declination Angle	Degrees	-0.52
Variable Declination Angle	Degrees	-0.52498

Substituting (2) into (3), we see the relation between the position of the earth satellite station and the elevation angle. In Table 2, we listed several locations in Malaysia that received the transmission of MEASAT 1 and MEASAT 3.

Minimum Elevation Angle of Receiver Antenna: The beam width of the satellite antennas determines the area of the earth serviced or covered and directly determines the antenna gain. With a given operating frequency, the physical size of the antenna aperture can also be determined [3].

To calculate the area of earth coverage, the distance between the satellite and the earth station must be determined. This can be done either by using the position of the earth stations or the elevation angle of the satellite. The application of both methods is clearly displayed using the satellite look angle calculator [9]. Table 3 indicate the relationship between the latitude and longitude and the elevation angle at several locations in Malaysia at MEASAT 3 while Figure 4 indicates different in elevation angle for the same location in MEASAT1.

It should be highlighted that before the migration of MEASAT 1 to MEASAT 3, the position of the satellite for both satellite is at 91.5°E with an elevation angle of 77.43°. However, MEASAT 1 now known as Africa Sat has been shift to a new position that changed the longitude of the satellite to 45.7987°E with an elevation angle of 22.995°E.

In comparing the range of link between satellite and earth station for MEASAT 3 as seen in Table 5 (taken from Table 2 and 3), it is clearly indicate that the distance calculated using the satellite look angle calculator produced a constant range while there are variation in the satellite range when using different position of the earth station as a reference. This is because the satellite look angle calculation takes into account all the possible link losses including the antenna offset angle when computing the satellite range.

By taking the constant range of 35958.21 km as the satellite orbit height, h (from table 5), 6370 km as the earth radius, R_e and the minimum elevation angle, θ for MEASAT 3 that is constant at 77.43°; the coverage angle, β [10] can be determine using:

$$\beta = \sin^{-1}\left[\left(\frac{R_e}{R_e + h}\right)\cos\theta\right] \tag{4}$$

Comparing the coverage area of MEASAT 3 to MEASAT 1, we can conclude that as the elevation angle increased, the coverage area is getting smaller. Thus, moving at higher elevation angle will see a decreased in the coverage area.

Environment Impact: Previous frequency range of 3700MHz to 4200MHz and 5925 MHz to 6425MHz is currently more or less reserved for communication between satellite earth station in MEASAT 1 and MEASAT 2 which will eventually prevent potential interference. At the same time, the usage of higher frequency prevent future interference between satellite earth stations and terrestrial microwave link that eventually give the benefit in term of flexibility in constellation design and speed up the commission of the services. Higher frequency communication systems also have the advantage of generally smaller system component which translate satellite that are lighter weight, lower power and at lower cost; as well as having higher mobility and flexibility [11].

The interference due to rain attenuation can be overcome in C-band through the link design that can achieved 99.99% reliability [12, 13] as the rain attenuation rarely exceed 1 to 2 dB for this band.

Economic Impact: The number of transponder for C-band has increased by double from 12 transponders for MEASAT 1 to 24 transponders for MEASAT 3. The increased in number of transponder has also increased the payload twice which means a larger number of user that can be accommodate and more services can be offered. MEASAT 3 has employed different techniques to determine number of channel per transponder which resulting in an increased of number of channel per transponder that used a much lower carrier power compared to MEASAT 1. As a result, more income is generated as the number of offered services increased and the total cost in operation is kept low. The drawback is since a transponder is an amplifier, the output power level is controlled by the input power and hence the saturated power level will correspond to the saturated output power level.

CONCLUSION

The migration of MEASAT 1 to MEASAT 3 for C-band Fixed Satellite Services (FSS) introduce some of the perks which see a greater selection of television channels with the availability of high definition television, more live telecast and easy access to the internet using high-speed connections, that will be available throughout the country. With the launch of MEASAT 3, it will provide wider C-band coverage to over 70% of the world's population and high powered DTH quality Ku-band coverage to over 160 million households.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Kebangsaan Malaysia for the support.

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