Interference and Compatibility Analysis of RF Communication Systems (MEASAT -Case Study)

Zulfiqar Ali Leghari[1], Abdul Rani Bin Othman[1] and Ghulam Muhammed[2]

[1]Faculty Electronic & Computer Engineering, Kolej Universiti Teknikal Kebangsaan
1200 Ayer Keroh, 75450 Melaka, Malaysia
[2]Faculty of Engineering & Technology Building, Multimedia University, Jalan Air Keroh Lama,
75450 Melaka, Malaysia
zulfiqar@kutkm.edu.my, rani@kutkm.edu.my

Abstract - The paper will demonstrate a case study of detailed Interference and Compatibility Analysis of MEASAT networks vis-à-vis affected satellite networks having the orbital separation less than 8°. For detailed interference and compatibly analysis of Measat-SA3 (37° E) and Paksat-2 (41° E) for C band uplink and downlink we have carried out analysis under ITU-R REC-740 [1]. The analysis demonstrates that two collocated satellite networks at the orbital separation of less than 5 degree can be operated in C-band for digital and analog communications without generating and accepting harmful interference [5]. For smooth and interference free transmission, both of the satellite networks have to be limited in radiating the power in up and down links. The analysis proposes power limits and constraints for both of the satellite systems for smooth and interference communications in both directions.

Keywords: Communication satellite, Interference Analysis, , Compatibility Analysis, Measat, Paksat, C-band

1. Introduction

MEASAT-1 was launched in January 1996 to the orbital location of 91.5ºE utilizing the C and Ku-band frequencies [4]. MEASAT-1 provides C-band coverage over the East Asia Region in the frequency range 5925-6425 MHz and 3700-4200 MHz, while Ku-band covers Malaysia, Indonesia, Philippines and India in the range 13.75-14.5 GHz and 10.95-11.2 GHz, 11.45-11.7 GHz & 12.2-12.75 GHz.[11].

MEASAT-2 was launched in November 1996 to the orbital location of 148ºE also utilizing the C and Ku-band frequencies. MEASAT-2 provides C-band coverage over East Asia, Australia and Hawaii in the frequencies range 5925-6425 MHz and 3700-4200 MHz, while Ku-band covers Malaysia, Indonesia, Vietnam, Taiwan, Philippines and Eastern Australia in the range 13.75-14.5 GHz and 10.95-11.2 GHz, 11.45-11.7 GHz & 12.2-12.75 GHz. In addition to MEASAT-3, there are also plans by BSS to launch two other satellites, MEASAT-1R and MEASAT-5 (or A-M SAT). MEASAT-5 will be launched to the orbital location of 5.7°E carrying 24 C-band and 12 Ku-band transponders. In the C-band, MEASAT-5 will carry a wide beam covering the African continent, while Ku-band will comprise of two beams, one fixed over Southern Africa and another with steerable capability. [11]

Pakistan brought its communication satellites in operation at 38°E and 41°E in December, 2002. The prime areas from marketing view point include South Asia, Europe, Middle East and Africa [12].

In order to ensure successful operation, to avoid harmful interference, and to observe the procedures of the ITU Radio Regulations, a RF System, prior to its operation, has to carry out interference and compatibility analysis to seek a co-ordination agreement with a number of administrations, which have filing priority in respect of their Radio-communication Networks [1]. In cases where the geocentric angle separation of the nominal orbital positions between the subject satellite network pairs is less than 8°, then the network would be subject to coordination in accordance with the provisions of the Radio Regulations. The satellite networks having orbital separation less than 8° that require detailed interference and compatibility analysis and frequency coordination with the affected radio-communication systems [1].

Satellites in GEO orbits are being co-located using orthogonal polarization to place more number of satellites to meet the demand. But while co-locating satellites operating in the same frequency band, careful system analysis and optimization is required to deal with cochannel interference. This paper studies the co-channel interference that may arise between co-located satellites employing frequency re-use and its effects on the system performance. The various sources of the interference are identified and modeled. The vulnerability of the system to the interference is assessed [2] [3].

Assessment of co-channel interference is very important for co-located satellites accessing overlapping frequency bands. Factors like insufficient cross-polarization isolation, poor antenna side lobe radiation's, power amplifier nonlinearities and improper filtering etc. may cause interference to the neighboring satellites [6]. In addition to this the input power flux densities for the co-located satellites may take different values due to different application requirements[10]..For example, one satellite supporting high power Direct-To-Home services may be co-located with another satellite supporting the DVB-RCS link employing low power signals for return channel. In such cases the co-channel interference effects are prominent even when other system parameters like cross-polarization isolation etc. are complying the specifications for the system link budget. The effect of co-channel interference can be reduced by using frequency staggering, carrier power enhancement, base band pulse shaping, antenna beam shaping etc. Here analysis for frequency staggering and carrier power enhancement case is presented [8].

2. Methodology

To compute the aggregate interference from a population of ES spread across the Earth's surface.

$$(C/I)_{uplink} = C - 10\log\left\{\sum_{i=1}^{N} 10^{(EIRP_{unwanted} + 10\log(n_i) - L_i + G_i)/10}\right\} \quad (1)$$

where, *(C/I)uplink* is carrier-to-interference ratio in dB, *C* is the desired carrier power in dBW *N* is the number of concentric rings in satellite field of view, *EIRPunwanted* is the unwanted EIRP from each interfering ES in dBW, *ni* is the number of ES in ring I, *Li* is the free space propagation loss from the inner edge of ring i in dB, *Gi* is the satellite receiving antenna gain at the corresponding off-axis angle in dBi. [1],[2],[9], [10].

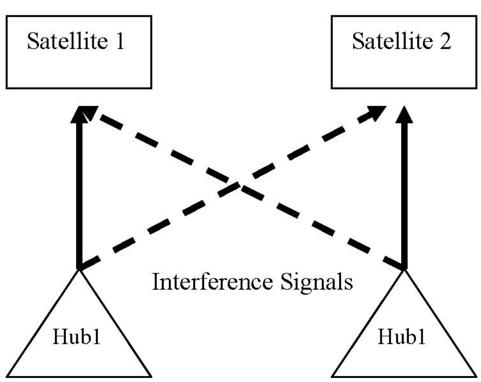

Figure-1: Interference Scenario.

We have applied the principles of coordination of satellite networks as per ITU Radio Regulations. For detailed interference and compatibility analysis, we followed ITU-R REC-740. The following general provisions were taken into account for detailed interference and compatibility analysis[1] [5],[7],[8].

i) FMTV carriers shall be always modulated with a live video signal or a test pattern in addition to the energy dispersal signal except for short duration testing [5],[7],[8].

ii) All figures of EIRP and EIRP spectral density agreed apply to the co-coverage case and may be relaxed by a value corresponding to the satellite antenna discrimination. Both operators will remain in contact in order to be aware of the actual satellite coverage to apply the aforementioned relaxation. In the case of uplinks, the value of satellite antenna discrimination is given by the difference between the interfered with network's peak satellite antenna gain and its gain in the direction of the interfering earth station. In the case of downlinks, the value of satellite antenna discrimination is given by the difference between the interfering network's peak satellite antenna gain and the interfering network's satellite antenna gain in the direction of the interfered with network's edge of service area [5],[7],[8].

iii) In the event that either side identifies a need to operate at levels exceeding those calculated in analysis or an operating satellite experiences actual unacceptable interference, then both operators will, go on a case-by-case basis, enter into detailed consultation, on good-will basis, in order to try and find mutually acceptable solutions [5],[7],[8].

In cases where the geocentric angle separation of the nominal orbital positions between the subject satellite network pairs is less than 10^{o}, then the network would be subject to coordination in accordance with the provisions of the Radio Regulations. The only cases of 1°, 4°, 5° and 8° separation that require detailed coordination are between PAKSAT-1 (38^{o}E), PAKSAT-2 (41^{o}E) and MEASAT-SA3 (37^{o}E), MEASAT-SA4 (46^{o}E), MEASAT-46E (46^{o}E) satellite networks.

3. Systems Analysis

MEASAT-1 was launched in January 1996 to the orbital location of 91.5ºE utilizing the C and Ku-band frequencies. MEASAT-1 provides C-band coverage over the East Asia Region in the frequency range 5925-6425 MHz and 3700-4200 MHz, while Ku-band covers Malaysia, Indonesia, Philippines and India in the range 13.75-14.5 GHz and 10.95-11.2 GHz, 11.45-11.7 GHz & 12.2-12.75 GHz.

Binariang Satellite Systems Sdn. Bhd. (BSS), the operator of MEASAT satellite networks has signed an agreement with Boeing Satellite Systems to build a new satellite MEASAT-3. Based on the Boeing 601HP spacecraft, MEASAT-3 will be launched in the 2nd quarter of 2005 to be co-located with MEASAT-1 at 91.5°E. MEASAT-3 will carry a payload of 24 C-band and 24 Ku-band transponders of 36MHz bandwidth. In C-band, MEASAT-3 will provide a global coverage, while in Ku-band it will be equipped with switchable beams over the coverage areas of Malaysia, India and China/Indonesia. [11]

Pakistan brought its communication satellites in operation at 38°E and 41°E in December, 2002. The prime areas from marketing view point include South Asia, Europe, Middle East and Africa. PAKSAT is developing a modern satellite to replace the existing satellite. Deliberations and efforts are being put in to develop satellite networks for the other orbital slots as well [12] .

4. Interference and Compatibility Analysis

For detailed interference and compatibly analysis of Measat-SA3 (37° E) and Paksat-2 (41° E) for C band uplink and downlink we have carried out calculations under ITU-R REC-740 due to the orbital separation between the two systems which is les than 10° E.

In cases where the geocentric angle separation of the nominal orbital positions between the subject satellite network pairs is less than 10°, then the network would be subject to coordination in accordance with the provisions of the Radio Regulations [1][3]. The only cases of 1°, 4°, 5° and 8° separation that require detailed coordination are between PAKSAT-1 (38°E), PAKSAT-2 (41°E) and MEASAT-SA3 (37°E), MEASAT-SA4 (46°E), MEASAT-46E (46°E) satellite networks.

Table 1: 5.927-6.323 Uplink Analysis.

	153KG7W--	307KG7W--	38K4G7W--	1M00F7W--	1M23G7D--	38K4G7E--	76K8G7D--	76K8G7E--
12K8GXX--	-5.3	-5.3	-5.3	-40.9	-10.7	-14.2	-8.6	-6.7
1M60GXX--	0.8	0.8	0.8	-34.9	-4.7	-8.1	-2.5	-0.6
27M0F3F--	6.4	6.3	6.4	-29.3	0.9	-2.5	3.1	5
36M0G7X--	9	9	9	-26.6	3.6	0.1	5.7	7.6
36M0GXW--	7.6	7.6	7.6	-28	2.2	-1.3	4.3	6.2
410KGXX--	-1	-1	-1	-36.7	-6.5	-9.9	-4.3	-2.4
51K2GXX--	-4.3	-4.3	-4.3	-39.9	-9.7	-13.2	-7.6	-5.7
64M0GXX--	10	10	10	-25.6	4.6	1.1	6.7	8.6
6M40GXX--	3.4	3.4	3.4	-32.2	-2	-5.5	0.1	2
1M00G9X--	-2.9	-2.9	-2.9	-38.5	-8.3	-11.8	-6.2	-4.3

Table 2: 5.927-6.323 Uplink Analysis.

	102KG7W--	12K8G7W--	1M64G7W--	25K6G7W--	51K2G7W--	5K80G7W--	819KG7W--	13M5F8E--
12K8GXX--	-31.4	-9.4	-31.4	-9.7	-31.4	-15	-31.4	0.9
1M60GXX--	-25.3	-3.3	-25.3	-3.6	-25.4	-8.6	-25.3	7
27M0F3F--	-19.8	2.2	-19.7	1.9	-19.8	-3	-19.7	9.5
36M0G7X--	-17.1	4.9	-17.1	4.6	-17.1	-0.4	-17.1	11
36M0GXW--	-18.5	3.5	-18.5	3.2	-18.5	-1.8	-18.5	9.5
410KGXX--	-27.2	-5.1	-27.1	-5.5	-27.2	-10	-27.1	5.1
51K2GXX--	-30.4	-8.4	-30.4	-8.7	-30.4	-14	-30.3	1.9
64M0GXX--	-16.1	5.9	-16.1	5.6	-16.1	0.6	-16.1	9.4
6M40GXX--	-22.7	-0.7	-22.7	-1	-22.7	-6	-22.7	9.6
1M00G9X--	-29	-7	-29	-7.3	-29	-12	-29	12

Table 3: 3.4035-3.6485 Downlink.

	1M23G7D--	38K4G7E--	76K8G7D--	76K8G7E--	1M00F7W--	2M00F7W--
12K8GXX--	-33.5	-29.4	-31.4	-29	-41.1	-24
27M0F3F--	-26.2	-22.2	-24.2	-22	-33.8	-17
36M0GXW--	-26.8	-22.7	-24.7	-23	-34.4	-17
51K2GXX--	-33.4	-29.4	-31.4	-29	-41.1	-24
1M60GXX--	-31.6	-27.5	-29.5	-28	-39.2	-22
410KGXX--	-31.6	-27.5	-29.6	-28	-39.2	-22
6M40GXX--	-31.2	-27.1	-29.1	-27	-38.8	-22
36M0G7W--	-25.6	-21.5	-23.5	-22	-33.2	-16
64M0GXX--	-23.1	-19	-21	-19	-30.7	-14
36M0G7X--	-25.6	-21.5	-23.5	-22	-33.2	-16

Table 4: 3.7-4.198 Downlink.

	38K4G7E--	76K8G7D--	76K8G7E--	2M00F7W--	409KG7D--	1M64G7D--
1M00G9X--	-5.7	-7.7	-5.7	-0.4	3.6	3.6
12K8GXX--	-29.4	-31.4	-29.4	-24	-20.1	-20
27M0F3F--	-22.1	-24.2	-22.2	-17	-12.9	-13
36M0GXW--	-22.7	-24.7	-22.7	-17	-13.4	-13
51K2GXX--	-29.4	-31.4	-29.4	-24	-20.1	-20
1M60GXX--	-27.5	-29.5	-27.5	-22	-18.2	-18
410KGXX--	-27.5	-29.5	-27.5	-22	-18.2	-18
36M0G7W--	-21.5	-23.5	-21.5	-16	-12.2	-12
64M0GXX--	-19	-21	-19	-14	-9.7	-9.7
6M40GXX--	-27.1	-29.1	-27.1	-22	-17.8	-18
36M0G7X--	-21.5	-23.5	-21.5	-16	-12.2	-12

5. Summary

The above analysis demonstrates that for interference free and smooth operation of two satellite networks MEASAT-SA3 at 37°E and the PAKSAT-2 at 41°E located at less than 10 degree orbital separation in both uplink and downlink in C-band, the operators are recommended to consider the following findings .

In order to ensure that unacceptable interference is not caused by the MEASAT-SA3 satellite network at 37°E into the PAKSAT-2 satellite network at 41°E, the Malaysian administration is to meet the following conditions for the MEASAT-SA3 satellite network at 37°E in the bands of 5925 – 6725 MHz and 3400 - 4200 MHz:

Uplink

i) The uplink off-axis EIRP density of digital carriers shall not exceed – 45.7 + 29 – 25 log (θ) dBW/Hz, under clear sky conditions.

Downlink

i) The downlink EIRP density of digital carriers shall not exceed – 39.3 dBW/Hz;
ii) The downlink EIRP of the 18M0F8F FMTV carrier shall not exceed 27 dBW;
iii) The downlink EIRP of the 32M0F3F FMTV carrier shall not exceed 32 dBW.

In order to ensure that unacceptable interference is not caused by the PAKSAT-2 satellite network at 41°E into the MEASAT-SA3 satellite network at 37°E, the Paktsat-2 will meet the following conditions for the PAKSAT-2 satellite network at 41°E in the bands of 5925 – 6725 MHz and 3400 - 4200 MHz:

Uplink

i) The uplink off-axis EIRP density of digital carriers shall not exceed – 36.8 + 29 – 25 log (θ) dBW/Hz, under clear sky conditions.

Downlink

i) The downlink EIRP density of digital carriers shall not exceed – 30.6 dBW/Hz.
ii) The downlink EIRP of FMTV carriers shall not exceed 40.8 dBW.

6. Conclusion

On the basis of the above analysis and conditions, both satellite networks (Measat and Paksat) can be operated without causing or accepting harmful interference. The above analysis can be helpful to complete the operating agreement under ITU-R Rec-740 coordination procedures between MEASAT-SA3 (37°E) and PAKSAT-2 (41°E) in the C-band of 5925 – 6725 MHz and 3400 - 4200 MHz.

References

[1] TU-R REC-739, 740, 741, 742, App 29, Radio Regulations Edition 2004, www.itu.int.

[2] ITU,"Handbook On Satellite Communications, ITU Publications, ITU HQs., Swizerland.

[3] Zulfiqar Ali Leghari *"Propose Satellite Ground Station Design Parameters for Ultra Speed Data Communications for Malaysia", May 15-17 ,UiT-IEEEM, 2006,* International Wireless and Telecommunications Symposium (IWTS'06), Grand BuleWave Hotel, ShahAlam, Malaysia

[4] Zulfiqar Ali Leghari *" Exploring National Space Assets for Malaysia", February 14-15, KUTKM,* National Seminar on Science and Its Applications (SSASI) 2006" Century Mahkota Hotel, Malacca.

[5] Zulfiqar Ali Leghari, *" Interference and Compatibility Analysis of two GEO Satellite located at 1° Orbital Separation", December* 20-21 2005, UiTM, UTM, IEEE AP/EMCAsia-Pacific Conference on Applied Electromagnetic (APACE2005) Johar Baru, Malaysia

[6] Zulfiqar Ali Leghari , *"Telemedicine via Satellite in Malaysia", April 5-7 2006* , The International Trade Event Conference for eHealth, Telemedicine and Health ICT (Med-e-Te2006), Luxembourg.

[7] Zulfiqar Ali Leghari ,*"Regulatory Aspects of Pakistan National Satellites Communications Systems*", October

9-15 , 2004, Iranian Space Agency (ISA), Islamic Development Bank (IDB), ISNET, “Satellite Technolgy Applications in Communication & Remote Sensing” Inter Islamic Network on Space Sceinec & technology.

[8] Zulfiqar Ali Leghari ,“*Technical Aspects of Potential / harmful Interference in Space Communications*.” November 13-19, 2003, Asia-Pacific Telecomm unity (APT) and Ministry of Public Management, Home Affairs, Post and Telecommunications of Japan, Tokyo, Japan,

[9] James R. Larson, Wiley J. Larson,” Space Mission Analysis and Design”, United States Air force Academy, Micro Press, El Segundo, California.

[10] Mark E. Long, “The Digital Satellite TV Handbook”Newness Press Publications, United States of America

[11] www.measat.com

[12] www.paksat.com.pk