White Paper

Coexistence of WiMAX and Satellite Networks in the 3.5GHz Band

Executive Summary

Concerns have arisen about possible interference between existing ommunications satellites and emerging wireless wide-area data networking using the Fixed WiMAX (IEEE 802.16-2004) standard, both of which operate in the extended C-band (3.4 GHz to 3.7 GHz).

Comprehensive investigation by Intel has shown that such concerns need not restrict the rollout of WiMAX technologies, as long as a few clear design guidelines are applied to the positioning of WiMAX base stations relative to satellite earth stations.

Depending on transmission strength, simulations have shown that the two communications technologies can coexist as long as the height of the WiMAX transceivers is kept as low as possible. Base stations should be kept at least 150 meters (at 20 watts EIRP) or 350m (at 250 watts EIRP) away from the satellite earth station (in an adjacent channel configuration), and at least 4 kilometers (at 20 watts EIRP) or 6 kilometers (at 250 watts EIRP) away from the satellite earth station (in a co-channel configuration). These are feasible design criteria that are quite easy to implement as most WiMAX rollouts are still in the very early stages.

This simulation was prepared for the Thaicom-3 satellite, but the results of the evaluation should be equally applicable to any extended C-band satellite around the world. Complete testing results are available in a separate document[1] available from Intel.

Introduction

WiMAX (IEEE 802.16) is an open standards based wireless transmission protocol that provides high-speed data services across a wide area. As with conventional mobile phones, WiMAX services are utilized by linking a data terminal to a subscriber-side access card or standalone modem, which connects to the nearest WiMAX base station in a one-to-many configuration.

Current WiMAX technology supports stationary as well as nomadic subscriber equipment, but a coming mobile iteration will provide for continuous WiMAX access while the subscriber is moving. This capability is expected to make WiMAX an extremely popular Internet access method for many customers in coming years, particularly as a growing number of WiMAX providers establish networks with broad coverage across major cities and large regional centers.

Background

Like many similar communications satellites, the Thaicom-3 satellite offers a payload capacity of 25 C-band and 14 Ku-band transponders, providing service across Asia, Europe, Australia and Africa. The Ku-band transponders provide highly focused spot broadcasting of high-capacity signals in the 12GHz frequency range, while the C-band transponders provide broader coverage using a 36MHz bandwidth each in the 3.7GHz to 4.2GHz frequency range and additional coverage using the extended C-band range (3.4 GHz to 3.7 GHz).

This operational profile promotes scrutiny relative to the risk of interference from emerging wireless data networking standards such as WiMAX, which provides a high-speed data connection within a large radius around the base station. WiMAX functions between 2 and 66GHz but is commonly being deployed in the 2.3GHz, 2.5GHz, 3.5GHz and 5.8GHz frequency ranges for cost-effectiveness and performance reasons.

Because they occupy the same radiofrequency bands, Thaicom-3 and WiMAX infrastructure may potentially experience interference if configured incorrectly. The purpose of this study was to evaluate the risk of such interference, and to develop recommendations for the deployment of WiMAX wireless networks in such a way as to avoid interference with satellite transmissions.

Simulation methodology

To evaluate the potential interference between the two signals, two scenarios were considered.

In the first, a WiMAX base station (BS) is installed in proximity to the satellite earth station (ES) that serves as a relay between the Thaicom-3 satellite and terrestrial networks, and is causing interference with the satellite signal as a result. This configuration would result from a poorly placed WiMAX BS and could, if not addressed properly, result in interference problems.

In the second scenario, an ES is installed in the middle of a number of WiMAX base stations, which will typically be deployed in a hexagonal mesh configuration across metropolitan areas (see figure 1). In this scenario, which would be relevant when WiMAX becomes more widely deployed, interference for the ES can result from a number of BS installations at the same time.

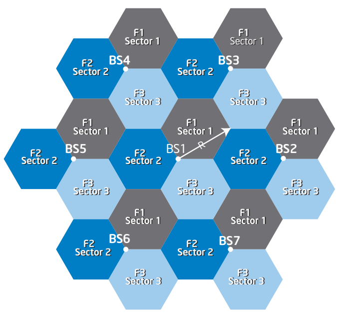

Figure 1. Arrangement of WiMAX cells in 1x3x3 frequency sharing configuration

In each case, simulations were run to evaluate the ideal height of the BS and ES, and the distance between them, to ensure that interference within the contended radiofrequency spectrum could be kept to a minimum or eliminated altogether. An FCC out of band spectral mask was used in both cases.

The ideal angle between the BS, ES and satellite, known as φ, was also calculated to determine the relationship between BS-ES distance, BS height, ES height, and interference levels. These levels were also evaluated in low-power (20 watt BS EIRP), high-density and high-power (250 watt BS EIRP) low-density configurations to determine the relative effect of increasing spacing between WiMAX base stations.

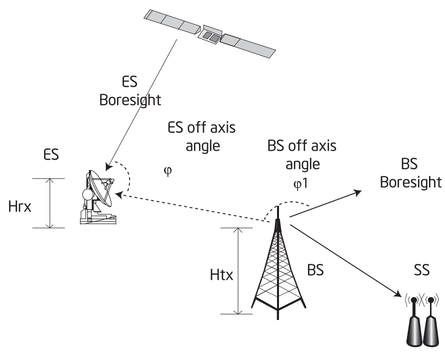

Figure 2. Relative position of WiMAX base station (BS), Thaicom-3 earth station (ES), and satellite. Adjusting the height Htx and Hrx reduces potential line-of-sight interference and optimizes the angle of incidence φ to increase interference rejection.

The simulation was conducted using the criteria I/N = -10dB using a variety of modulation methods as follows:

Modulation code name	Required C/N	Minimum permissible C/I
QPSK-DVB-RS 1/2	3.8	13.8
QPSK-DVB-RS 2/3	5.6	15.6
QPSK-DVB-RS 3/4	6.6	16.6
QPSK-DVB-RS 7/8	8.2	18.2

Results

Simulations revealed that co-existence between the Thaicom-3 satellite signal and terrestrial WiMAX networks is feasible using a number of different scenarios:

1. The minimum feasible distance between the WiMAX BS and Thaicom-3 BS is 150 meters, using a 1x3x3 frequency protection configuration with a 20-watt BS EIRP, φ of 48° and a minimum cell radius of 577 meters. This configuration with a small cell radius would be appropriate in heavily populated areas.
2. Using a similar configuration with a high-power (250 watt) BS EIRP, the WiMAX cell radius could also be expanded to more than 577 meters, keeping interference within acceptable levels, provided the BS-ES distance was at least 350 meters.
3. To share the same spectrum with WiMAX, it would be necessary to adopt a co-channel approach in which WiMAX and Thaicom-3 systems share the same band. In this configuration, the WiMAX BS and Thaicom-3 ES heights are offset to optimize the angle φ and the BS is kept as low as possible, to minimize potential line-of-sight interference. A low-powered (20 watt) BS EIRP would provide feasible WiMAX cell radius of approximately 5km, keeping interference within acceptable levels as long as the BS-ES distance was at least 4km.

4. The final possible configuration involves a co-channel approach and high-powered (250 watt) BS EIRP. In this configuration, the minimum WiMAX cell radius would approach 10km, making it suitable for regional areas where population density is lower. This configuration would keep interference with Thaicom-3 below acceptable levels as long as the BS-ES distance was kept to a minimum of 6km.

Recommendations

Extensive simulation by Intel has confirmed that it is possible for WiMAX and extended C-band satellite signals to coexist without causing undue interference to either signal, as long as minimum distances between WiMAX base station and satellite earth station are observed as previously described.

Intel offers the following recommendations for minimizing interference:

1. WiMAX base stations should be deployed so the angle off axis from the earth station bore sight, φ, is at least 48° and the angle φ1 from the base station antenna bore sight to the earth station is as large as possible (see figure 2).
2. WiMAX base stations should be deployed to avoid line of sight with the earth stations.
3. Height of WiMAX base stations and earth station should be as low as possible, in order to avoid line of sight. This configuration with BS as low as possible also reduces interference by increasing the angle between the WiMAX base station and earth station bore sight.
4. In a co-channel scenario (3 and 4 above), distance between the WiMAX base station and satellite earth station should be more than the minimum distances specified (4km for cell radius ≥ 5km with 20 watt EIRP, and 6km for cell radius ≥ 10km with 250 watt EIRP).
5. Using different frequency bands between the earth station and its local sector can further reduce the minimum permissible distance between the earth station and WiMAX base station.
6. In an adjacent-channel scenario, the distance between the WiMAX base station and satellite earth station should be more than the minimum distances specified (150m for cell radius ≥ 577m with 20 watt EIRP, or 350m for cell radius ≥ 577m with 250 watt EIRP).
7. Use of different frequency bands is especially recommended when sector radius is reduced down to the hundreds of meters.
8. If WiMAX and the Thaicom-3 earth station are using adjacent frequency bands, a high-quality channel filter and power amplifier could be used to further reduce adjacent channel interference.
9. In the adjacent band scenario, the space between the earth station and its local sector should be kept as large as possible to minimize interference.

[1] "Sharing Studies between WiMAX (FBWA) and Thaicom Satellite System in 3.5 GHz band" Internal Document, Intel 2006