Interference Analysis from S-DAB into T-IMT-2000 in 2630~2655MHz

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Abstract: This paper is an interference analysis from S-DAB(Satellite-Digital Audio Broadcasting) into terrestrial IMT-2000 systems intending to use the band 2 630-2 655 MHz and that could be used to determine the impact of S-DAB on terrestrial IMT-2000 in the context of co-frequency sharing through the development of pfd masks.

1. INTRODUCTION

This paper is an interference analysis from S-DAB(Satellite-Digital Audio Broadcasting) into terrestrial IMT-2000 systems intending to use the band 2 630-2 655 MHz and that could be used to determine the impact of S-DAB on terrestrial IMT-2000 in the context of co-frequency sharing through the development of pfd masks.

The methodology contained in this paper can be used to calculate a single entry pfd mask for S-DAB for a given scenario to meet an Isat/Nth criterion within a tolerance of 1 dB. This paper shows the application of a methodology assessing the possible impact in terms of a loss of coverage or cell size reduction. It has been recognized that the interference into a cellular network can be assessed in terms of coverage reduction (particularly in noise-limited networks such as in rural areas) as well as in terms of availability reduction (particularly in capacity-limited networks such as in urban areas). These approaches may be complementary, and additional study is required on these further aspects.

The use of this approach to calculate pfd values in the context of co-frequency sharing should carefully take into account all parameters including operational constraints on BSS (sound) systems, as well as the likely different IMT-2000 sharing scenarios. In particular, it should be noted that if this approach is used to derive pfd values to be applied as hard limits, worst-case assumptions are not deemed appropriate.

2. SCENARIO AND METHODOLGIES

A given scenario will consist of S-DAB networks using non-GSO space stations employing highly-elliptical orbits (HEO) and/or space stations using the GSO interfering into terrestrial IMT-2000 systems (base and/or mobile stations).

The required T-IMT-2000 system parameters are given below

Receiver characteristics:

- thermal noise level;
- noise factor.

Antenna characteristics:

- maximum gain;
- polarization;
- feed loss;
- 3 dB beamwidth;
- vertical and azimuthal antenna radiation patterns over a range of elevation angles;
- downtilt of the antenna;
- site sectorization.

Location of the receivers (for example, an area bounded by latitude(s) and longitude(s) data).

The various combination of a constellation of S-DAB systems that could operate in the 2 630-2 655 MHz band should be in accordance with the expected number of co-frequency satellites visible at the same location on the surface of the Earth. These may include non-GSO and/or GSO satellites.

GSO satellites, assumed equally spaced across the GSO arc:

- nominal geographical longitude on the geostationary satellite orbit.

For non-GSO HEO satellite systems, the following parameters are to be provided:

- number of orbital planes, number of space stations per orbital plane and number of space stations simultaneously transmitting on the active arc, period of the space stations;
- altitude and longitude of the apogee and perigee for each space station;
- inclination angle for each orbital plane with respect to Earth equatorial plane;
- start and end of the active arc for each space station.

Interference produced by BSS (sound) satellites is typically modelled by pfd masks as a function of elevation angle (dB(W/(m^2 · MHz))).

The calculation steps for the aggregation of the interference from multiple satellites into a given IMT-2000 base station receiver is summarized below:

considering a set of non-GSO and/or GSO satellites orbiting around Earth;

- considering assumed pfd masks at the Earth's surface used to model the emissions of each non-GSO and/or GSO satellite;
- considering an IMT-2000 base station with sectoral antenna, characterized by its latitude, longitude, orientation and tilt angle;
- calculate the azimuth, elevation and off-axis angles between the IMT-2000 base station and each satellite of the assumed constellation;
- calculate the aggregate interference at the receiver entrance from all visible satellites (i.e., whose elevation angle is positive) with an overlapping bandwidth with terrestrial IMT-2000 and the subsequent Isat/Nth IMT-2000 base station receiver (sector) at a given latitude and longitude (lat, long), and pointing in a given direction (orientation, tilt angle). The subsequent Isat/Nth is given by the following formula:

$$\frac{Isat}{Nth}\left(\begin{array}{l} lat, long, orientation, \\ tilt\ angle \end{array}\right) = 10 \log \left(\begin{array}{l} \frac{1}{Nth} \sum_{i=1}^{n\_sat} 10^{\,(pfd_i(elevation\_i)} \\ + G(r\_azimuth\_i, r\_elevation\_i) \\ + 10 \log(\lambda^2/4\pi) - FL - P_i)/10 \end{array}\right) \quad (1)$$

Isat/Nth (*lat, long, orientation, tilt angle*): the resulting aggregate *Isat/Nth* from all visible space stations with an overlapping bandwidth with terrestrial IMT-2000 at the IMT-2000 receiver (dB)

$pfd_i(elevation\_i)$: pfd at the terrestrial IMT-2000 station from visible BSS (sound) space station *i* (dB(W/($m^2 \cdot$ MHz)))

elevation_i: elevation of the space station *i* seen from the IMT-2000 base station (it is the angle of arrival of the space station *i* incident wave to the IMT-2000 base station, above the horizontal plane) (degrees)

G(r_azimuth_i, r_elevation_i): off-axis gain of the IMT-2000 base station sector towards the space station *i* (dBi)

r_azimuth_i: relative azimuth of the space station *i* seen from the IMT-2000 base station sector (it is determined by the difference between the azimuth of the space station *i* seen from the base station and the azimuth of the orientation of the IMT-2000 base station sector) (degrees)

r_elevation_i: relative elevation of the space station *i* (the angle of arrival of the space station *i* incident wave to the IMT-2000 base station, above the horizontal plane, plus the tilt angle of the IMT-2000 base station (a downtilt angle has a positive value)) (degrees)

FL: terrestrial IMT-2000 receiver feeder loss (dB)

P_i: expected averaged polarization discrimination between transmitting antenna of space station *i* and the IMT-2000 base station receiving antenna (dB)

n_sat: number of satellites

Nth: terrestrial IMT-2000 station receiver thermal noise (W/MHz)

In the orbit simulation approach, the HEO satellite is transmitting from its simulated location on the active arc at each time increment and equation (1) is computed for each time increment (*t*) and becomes equation (2)

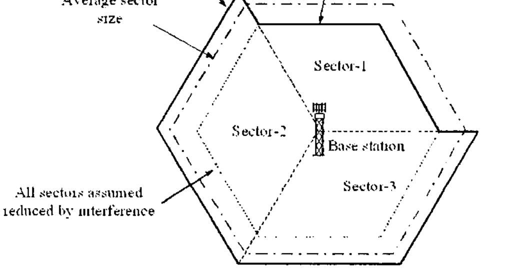
$$\frac{Isat}{Nth}\left(\begin{array}{l} lat, long\, orientatin, \\ tilt\, anglet \end{array}\right) = 10 \log \left(\begin{array}{l} \frac{1}{Nth} \sum_{i=1}^{n\_sat} 10^{(pfd_i(elevation\_i(t))} \\ + G(r\_azimuth\_i(t), r\_elevation\_i(t)) \\ + 10 \log(\lambda^2/4\pi) - FL - P_i(t))/10 \end{array}\right) \quad (2)$$

In addition to the assessment of the interference received at an IMT-2000 individual sector, it may be of interest to consider also the impact of the interference into IMT-2000 sites, taking into account the combined impact on each sector area.

The combined impact of the satellite interference over a site is to be evaluated in regard to the particular concerns of the scenario envisaged. For example, in cases where rural areas are of special concern, the impact on the loss of coverage is of the more critical impact on the system, and additional base stations would be required to overcome the effect of the interference. In this case, the interference threshold can be specified as an *Isat/Nth* derived from a loss of coverage analysis. In other words, it is also an evaluation of the percentage of the number of base stations needed to overcome the effect of interference on an IMT-2000 site deployment scheme.

With single sector cells, using azimuth independent antennas, this *Isat/Nth* can be directly compared against the value determined during simulation. However, with three sectors/cell, and if each sector has its own receiver, then three *Isat/Nths* will be calculated.

Figure 1 shows the key elements that need to be considered



calculate the average loss of coverage over the three sectors and convert back into an *Isat/Nth*, which is equivalent to assuming cell planning optimizes the network such that the distance between BS varies by azimuth to exactly adjust for interference:

$$\Delta A_{cell}\left(\frac{Isat}{Nth}\right)=\frac{1}{3}\left(\begin{array}{l}\Delta A_{sector1}\left(\frac{Isat_{sector1}}{Nth}\right)\\ +\Delta A_{sector2}\left(\frac{Isat_{sector2}}{Nth}\right)\\ +\Delta A_{sector3}\left(\frac{Isat_{sector3}}{Nth}\right)\end{array}\right) \quad (3)$$

where A_{cell} is the average cell site area in presence of interference, as a combination of each compounding sector areas $A_{sector1}$, $A_{sector2}$ and $A_{sector3}$, which are the sector areas for cells 1, 2 and 3 receiving interference $Isat_{sector1}$, $Isat_{sector2}$ and $Isat_{sector3}$ respectively.

3. SIMULATION RESULTS

This Section describes the results to derive *Isat/Nth* levels to protect terrestrial IMT-2000 systems from interference from BSS (sound) systems, based upon an *Isat/Nth* criterion. This Appendix addresses terrestrial IMT-2000 systems employing CDMA standards.

This approach is based on the following assumptions:

- interference is particularly problematic in coverage-limited environments;
- a particularly sensitive environment as in the case of a lightly loaded rural uplink;
- typical base station heights for rural environments would be 30 m;
- a suitable propagation model that can be used for rural environments;
- an acceptable loss of coverage or requirement for additional base stations expressed respectively as ΔA_{cell} and $BS_{increase}$.

These assumptions are used in the following algorithm:

- for the traffic levels of a typically lightly loaded rural cell, the uplink load factor is calculated and hence noise rise (dB);
- using the load factor, and assuming a suitable propagation model that can be used for rural environments, calculate the coverage loss that would result from a range of *Isat/Nth*; the resulting table is then used to convert a cell coverage loss ΔA_{cell}, back into the adjusted *Isat/Nth*.

The calculation step of the uplink noise rise (between thermal noise to system noise) as the baseline for lightly loaded rural cells is as followed.

$$Noise\ rise\ (n_i)=\frac{I_{total}}{P_N}=\frac{1}{1-\eta_{UL}} \quad \text{dB} \quad (4)$$

where:

I_{total} :total received wideband intercell and intracell interference power (dB(W/MHz))

I_{total} :noise power (dB(W/MHz))

η_{UL} :uplink load factor, calculated using:

$$\eta_{UL}=(E_b/N_0)\frac{RN}{W}\nu(1+i) \quad (5)$$

E_b/N_0 : energy per bit divided by noise spectral density required to achieve required quality of service

R :average bit rate (Mbit/s)

N :number of users per cell

W :CDMA chip rate (Mchip/s)

ν :activity factor (the average time ratio during which the transmitter is active)

i : other cell interference to own cell interference ratio.

Assuming an E_b/N_0, activity factor, and other cell interference to own cell interference ratios, the cell throughput = RN can be varied to calculated the uplink load factor and hence the noise rise.

Data set		
Traffic type	Voice	Data
Average bit rate R (Mbit/s)	0.0122	0.144
E_b/N_0 required (dB)	5.0	1.5
Activity factor, ν	0.67	1
Other cell to own cell interference ratio, i, for macro cell omni directional antenna (%)	55	55
CDMA chip rate, W (Mchip/s)	3.84	3.84

From these parameters, plots of noise rise against cell throughput were produced

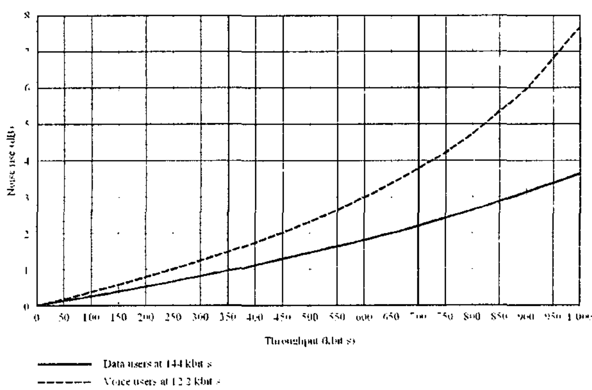


fig 2. CDMA uplink noise rise as a function of data throughput

Noise rises of 0.5, 1.0 or 2.0 dB corresponds to the following number of users

Noise rise, n_i (dB)	0.5	1.0	2.0
Voice users	10.7	20.5	36.5
144 kbit/s data users	1.3	2.5	4.5
Uplink load factor	0.1	0.2	0.4

For lightly loaded cells – for example in a rural area – there could be a handful of voice calls and a single data user. For these cells there would be a very low noise rise – for example in the range 0.5-1.0 dB. An alternative value that could be considered is 2 dB – however it should be noted that this would be a significant variation from the assumption of a lightly loaded rural cell.

For coverage limited cells, such as would be the case for rural environments, the impact of interference is to decrease the range of a cell. This is a degradation in the propagation loss available in the link budget, ΔL, which can be calculated as:

$$\Delta L = 10\log_{10}\left(1+10^{(Isat/Nth)/10}\right) \quad (6)$$

where the total noise N is dependent upon the thermal noise, N_{th}, and the noise generated by CDMA system (intracell and intercell) interference, N_{sys}, as follows:

$$N = N_{th} + N_{sys} \quad (7)$$

From the above, the noise rise, n_i from thermal to total noise has been calculated, and hence the equation (6) becomes:

$$\Delta L = 10\log_{10}\left(1+10^{((Isat/Nth)-n_i)/10}\right) \quad (8)$$

This loss in propagation margin, L, can be converted into a loss of range, D, using a suitable propagation model, such as the Hata model for open environments using base station height of 30 m, e.g.:

$$L = 106.2 + 35.2\log_{10} D \quad (9)$$

Hence the change in range, ΔD, for a given degradation in the propagation loss is:

$$\Delta D = 10^{-\Delta L/35.2} \quad (10)$$

As the change in area, ΔA, is proportional to the square of the change in range, then:

$$\Delta A = \left(10^{-\Delta L/35,2}\right)^2 \quad (11)$$

Combining equations (6) and (11) we derive:

$$\Delta A\left(\frac{I_{sat}}{N_{th}}\right) = \left\{1+10^{((I_{sat}/N_{th})-n_i)/10}\right\}^{-20/35.2} \quad (12)$$

Equation (12) is used to evaluate the loss of coverage in each sector of an IMT-2000 base stations cell or site. For a tri-sectoral IMT-2000 base station site, the global loss of coverage of the cell/site is obtained by averaging the results obtained for each separate sector of the cell

The increase in the number of required base stations is related to the area reduction due to interference. This is given by:

$$BS_{increase} = \frac{NumBS_{WithInterference}}{NumBS_{WithoutInterference}} \quad (13)$$

The number of base stations required can be estimated by:

$$NumBS_{WithoutInterference} = \frac{TotalArea}{AverageBSArea_{WithoutInterference}}$$

(14-1)

$$NumBS_{WithInterference} = \frac{TotalArea}{AverageBSArea_{WithInterference}}$$

(14-2)

If the coverage area of a BS reduces by factor ΔA, then the number of base stations will increase by the reciprocal of this factor.

For various $Isat/Nth$ and n_i values we can derive the associated coverage area loss and hence requirement for additional base stations, as shown in Fig. 4 and Table 3. The Table is then used to convert back the global loss of coverage of an IMT-2000 cell/site to obtain the adjusted $Isat/Nth$ values

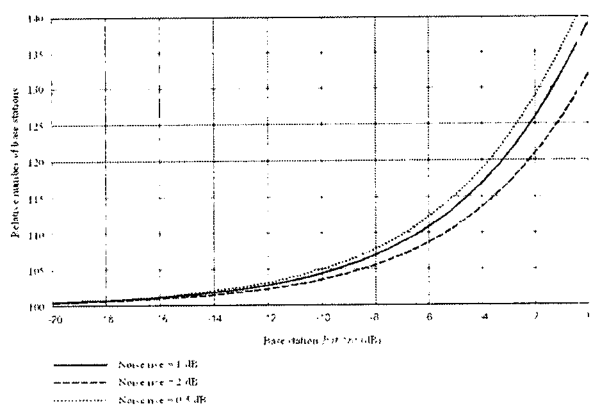


fig 3. Impact on coverage of base station Isat/Nth for noise rise = 0.5, 1 and 2 dB

4. CONCLUSION

The simulation method described above could be used to assess interference from, and possible impact of, BSS (sound) on terrestrial IMT-2000 systems intending to use the band 2 630-2 655 MHz in the context of co-frequency operation through the development of pfd masks. In particular, it should be noted that if this methodologies is used to derive pfd values to be applied as hard limits, worst-case assumptions are not deemed appropriate.