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FEDERAL COMMUNICATIONS COMMISSION
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Via Hand Delivery

Magalie Roman Salas, Secretary
Federal Communications Commission
445 12th St., S.W., Room TW-B204
Washington, D.C. 20554

Re: Ex Parte File Nos. 48-SAT-P/LA-97, 89-SAT-AMEND-97, 130-SAT-AMEND-98, Docket No. ET 98-206

Dear Ms. Salas:

On behalf of SkyBridge L.L.C, the attached memorandum is transmitted for filing in the above-referenced proceeding. Copies of the memorandum are being distributed to the Commission staff indicated below.

If there are any questions regarding this matter, please contact the undersigned.

Respectfully submitted,

Jeffrey H. Olson
Attorney for SkyBridge L.C.C.

Enclosure

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Implementing "Home Zone" as a Default Solution for Ku-Band NGSO/NGSO Sharing

Introduction

Spectrum is a scarce resource that multiple broadband NGSO systems plan to use in Ku-band. To permit their co-existence, coordination is the optimum technique. Coordination is the most appropriate way to permit simultaneous co-frequency operations, as it offers solutions that are adapted to the dynamic environment of the NGSO systems, based on detailed characteristics of the design and operation of each system. Moreover, coordination permits the operators to maintain an equitable balance of constraints among the systems.

Although coordination is the preferred sharing method, successful coordination requires good faith participation by existing systems operators and each new entrant, particularly given the complexity of the NGSO systems involved. It can therefore not provide regulatory certainty that all entrants will be fairly accommodated. For this reason, a *default* solution is required, which would be invoked in case of a failure of coordination.

A default solution should meet several objectives:

-It should first provide equal treatment to all the systems. They should all be given the same opportunity to offer new and innovative FSS services.

-It should create an incentive for systems to coordinate. Proposing to applicants a default solution that would make them "equally un-happy" would encourage them to develop more optimum solutions through a coordination process.

-It should nonetheless be an economically viable solution. For instance, based on the assumption that seven systems seek access to the spectrum, a broadband system simply cannot operate over 1/7 of the spectrum offered in the Ku-band for NGSO systems, and therefore band segmentation as a default solution would doom the systems. Because financial institutions are very sensitive to the consequences of an even unlikely default scenario, the economic aspect of this problem should not be neglected.

-The default solution should also give the FCC regulatory certainty, i.e., the solution should be clearly and fully defined today, and not leave open issues to be solved as operators deploy their systems. An additional requirement for the default solution is it should not require any micro-management from the FCC.

The "Home Zone" Solution and How it Works

The Home Zone Concept

One of the default solutions that has been proposed is based on the "Home Zone" concept. In short, this technique is an enhancement of the "Home Spectrum" approach,[1] adapting it to the specific characteristics of the Ku-band and the NGSO FSS systems that will operate in this band. In fact, the Home Zone is the application of the Home Spectrum concept *only* when in-line or near in-line events occur (*i.e.*, when high interference levels may occur). This exploits the antenna discrimination inherent in all of the proposed NGSO FSS system designs. In all other configurations (*i.e.*, when the angular separation between the constellations is large enough to protect the receivers) the entire spectrum can remain available for use by each system.

The Home Zone of a NGSO satellite can be visualized as a contour around that satellite. More specifically, as seen below, the Home Zone is defined as a cone, emanating from the Earth station the satellite serves. The axis of the cone intersects the satellite and the Earth station, and the aperture angle of the cone is defined by the contour around the satellite. The cone represents the angular separation needed to protect other systems from harmful interference caused by communications between the satellite and Earth station.

When a satellite from one system enters the Home Zone of another satellite, the spectrum is divided between the two systems, and each system can employ half of the NGSO FSS spectrum to communicate with the affected satellites. At

[1] "Home Spectrum" refers to a scenario in which the available bands are split among the number of applicants (while permitting temporary access to unused slots). Although this technique provides equal access to spectrum, in this case it ignores the possibility of efficient spectrum sharing among the proposed Ku-band NGSO FSS systems.

all other times, the entire spectrum is available for each system.

This technique provides a more efficient use of the spectrum, because available bands are reduced only when high interference level configurations occur. In addition, with this technique, an interference configuration over one specific area does not require a reduction in the available spectrum for all satellites of a constellation over all areas.

The figure below illustrates the spectrum available for an NGSO satellite to serve an Earth station, showing the changes that occur as its Home Zone intersects the location of another NGSO satellite. On the left, all of the spectrum (sub-bands F1 and F2) is available to the satellite/Earth station pair shown.[2] Later on, when the other satellite appears in its Home Zone, the spectrum is split between the systems: the first satellite will use the F1 sub-band and the other satellite the F2 sub-band. When its Home Zone is again clear, the first satellite can use all of the spectrum again.

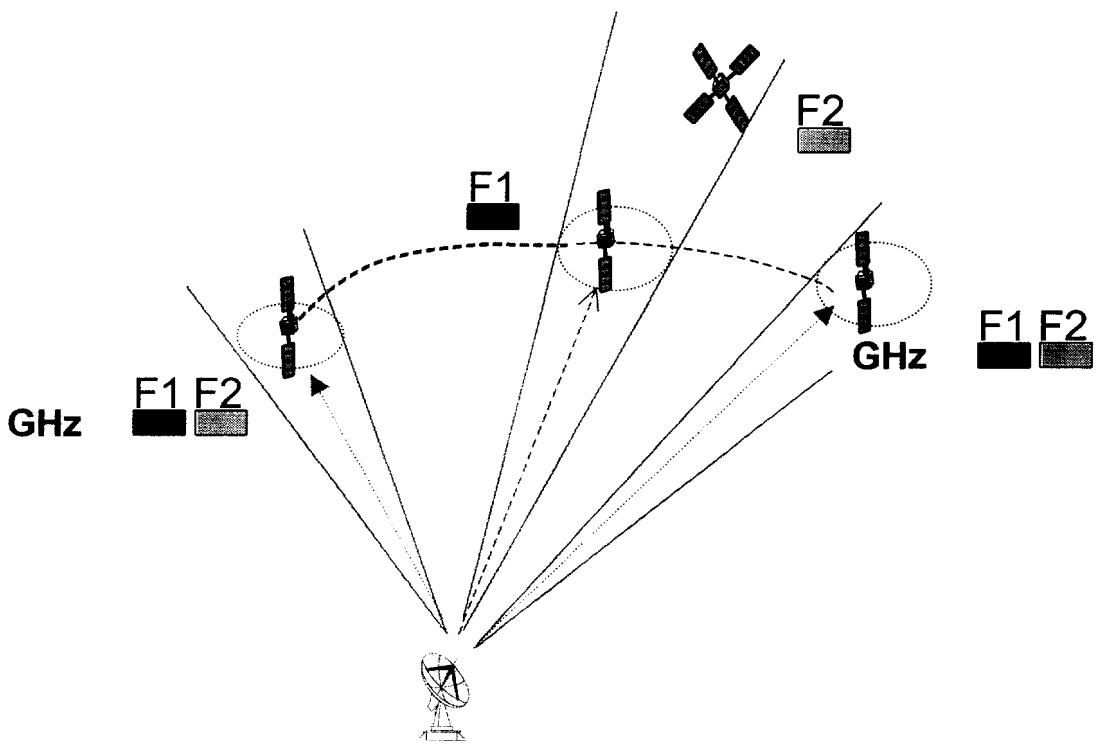


Figure 1: Dynamic Example

[2] The situation is symmetrical and could be assessed the same way from the other satellite's perspective.

Defining the Home Zone

In order to apply the Home Zone solution, a system requires only the locations of the other system's satellites. This simple formula permits the Home Zone concept to be easily automated by each system operator.

A comparison can be made to the NGSO/GSO sharing case, where NGSO systems ensure geometrical protection of the GSO systems knowing only the location of the GSO arc. In that case, although the GSO earth stations can be located anywhere, it is known that, no matter where they are located, they are all pointing somewhere along the GSO arc. This knowledge is sufficient for the NGSO operators to maintain sufficient angular separation from all GSO network links. Knowledge of the number and/or locations of the GSO earth stations is not necessary. In the NGSO/NGSO sharing case, it similarly is known that all the Earth stations of each NGSO system, no matter where they are located, are all pointing to satellites of their NGSO system. Just as in the NGSO/GSO sharing case, knowledge of the location of the satellites of the protected systems is all that is required to avoid interference configurations.

The size of the Home Zone cone must be developed to address both the uplink and downlink interference cases. That is, the cone must take into account the impact of both: (1) the interference from the system A Earth station into the satellite of the system B constellation (Cf. Picture 2), and (2) the interference from the satellite of system A into a system B Earth station (Cf. Picture 3).

The system A Home Zone cone protects system B from harmful interference. That is, a Home Zone is defined with the interfering system as the reference.[3]

[3] Of course, system B is also an interferer for system A, and the Home Zone approach has to be applied to both systems.

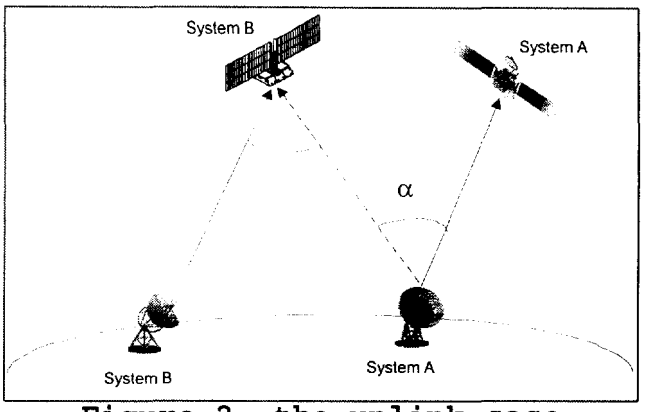


Figure 2: the uplink case

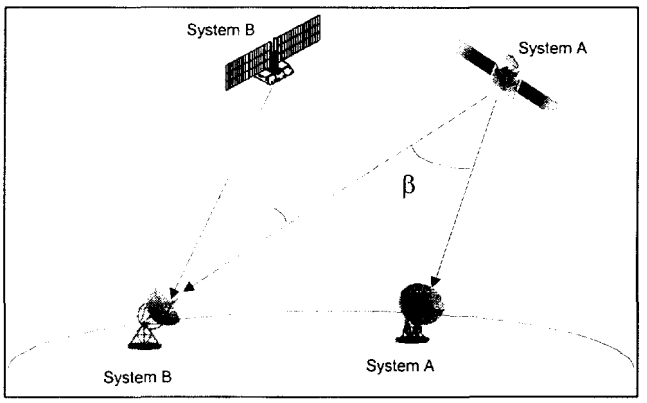


Figure 3: the downlink case

To take into account both uplink and downlink interference, both Earth-based and satellite-based angles are employed. Those 2 types of angles can be interchangeably employed[4]: However, as the Home Zone is referenced from the interfering system, some specific angles will be more convenient to describe the interference configuration.

First, to take into account the impact of uplink interference, an Earth-based angle is used. As shown in Picture 2 above, the α angle identifies the satellites of the interfering system that the Earth stations of the interfering system can communicate with without causing interference to victim satellites.

Second, to take into account the impact of downlink interference, a satellite-based angle is used. As

[4] Material that converts satellite-based and Earth-based angles has already been developed. See Technical Note of Document WP 4A/148 from the last study period.

illustrated in Picture 3 above, the β angle ensures a sufficient angular separation between the served and the victim Earth stations. This angle helps the NGSO operator to easily visualize the coverage of his satellites protecting, via the β angle, the Earth stations of the other system.

The picture below illustrates the use of both α and β angles for a MEO system protecting a LEO constellation.

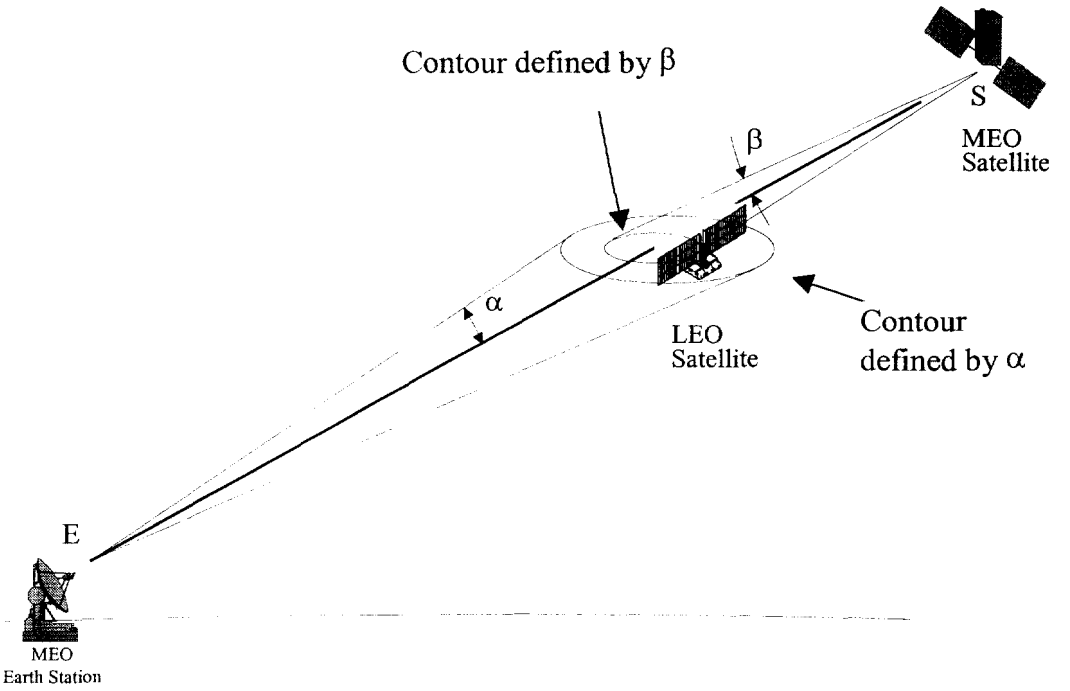


Figure 4

In the figure above, β represents the separation needed to protect the victim LEO earth stations from MEO satellite emissions, and α represents the separation needed to protect the victim LEO satellite from MEO earth station emissions.

Thus, the uplink and downlink protection requirements generate 2 contours around the protected satellite. The proper aperture of the Home Zone cone will be defined from the largest contour.

Simulations

Simulations have been run to assess the technical feasibility of the Home Zone solution.

Home Zone Events Involving Two Systems

A first set of simulations assess the time statistics of the angular separation between the constellations described in the Ku-band NGSO FSS applications on file with the Commission.

System models have been run in pairs: at each time step, the smallest separation Earth-based angle between all the available satellites of the 2 constellations is computed. Satellite availability for each system is based on the constellation tracking strategies for the system, which are typically confined by the minimum elevation limit and limitations used for the protection of the GSO arc.

For the simulations, the angles are computed from an Earth station located at 40N and 100W.

The results below express the percentage of time when constellations are separated by at least 5, 10, 15 and 20 degrees, as seen from the reference Earth station.

	SkyBridge	Boeing	HNet	Virgo	HLink	KuBs	Pentriad
SkyBridge							
5		96	84.5	97	92.6	83	96.5
10		83.8	56	88	75.5	45.7	85.8
15		64	30	72	55.5	13.3	66.8
20		42.0	13	50	37	1	39.7
Boeing							
5	96.0		96.7	96	92.6	91	93
10	83.8		87	71	75.5	69	80.4
15	64		73	47	55.5	36	50.6
20	42.0		58	30	37	13	30.3
HNet							
5	84.5	96.7		97	93	85	97.5
10	56	87		90	78.5	55	89.5
15	30	73		79	62	29	77.7
20	13	58		66	45	13	64
Virgo							
5	97	96	97		98	89	71.5

10	88	71	90		95	63.7	33.6
15	72	47	79		87	36	7.9
20	50	30	66	50	73	9	1.61
Hlink							
5	92.6	92.6	93	98		97	98.8
10	75.5	75.5	78.5	95		84.5	94.8
15	55.5	55.5	62	87		57.5	87
20	37	37	45	73		33.7	74.4
KuBs							
5	83	91	85	89	97		92.2
10	45.7	69	55	63.7	84.5		70.5
15	13.3	36	29	36	57.5		38.1
20	1	13	13	9	33.7		9.6
Pentriad							
5	96.5	93	97.5	71.5	98.8	92.2	
10	85.8	80.4	89.5	33.6	94.8	70.5	
15	66.8	50.6	77.7	7.9	87	38.1	
20	39.7	30.3	64	1.61	74.4	9.6	

Table 1

From Table 1, we can easily extract the percentage of time Home Zone events would occur. For example, HLink and Boeing would have 2 satellites closer than 10 degrees for 100-75.5 = 24.5% of the time. This means that the Home Zone configuration would occur during 24.5% of the time for a 10 degree Home Zone cone aperture as seen from the Earth-station.

A general conclusion from the simulations is that the larger the number of satellites a constellation has, the greater the number of Home Zone events. The SkyBridge/HNet case is a good illustration of this behavior.

An explanation for this observation can be drawn from the way the simulation has been designed. Because it computes all the possible configurations involving all the satellites available, a larger number of satellites will increase the number of cases where 2 satellites are close.[5]

[5] In addition, altitude seems to be a factor for MEO orbits. For example, the results for the KuBs constellation, which employs the lowest satellite altitude, show a noticeably high number of Home Zone events.

However, *these simulations do not represent the burden of Home Zone solution for the NGSO operators*, because all the satellite available will not be employed at the same time. In fact, typical traffic loading algorithms specify only one satellite (usually the one with the best elevation) serving a given area. Thus, a second set of simulations has been run with new assumptions. In this case, a reference constellation is chosen for each simulation, and the assumption is made that it always uses the highest elevation satellite to serve the Earth station. Angles are computed between that reference link and all the satellites of a second constellation.

Co-existing constellation	SkyBridge	Boeing	HNet	Virgo	HLink	KuBs	Pentriad
Reference constellation							
SkyBridge							
5		98.5	96.6	99.1	98.8	95.5	99
10		93.5	88.97	96.2	95.4	82	95.3
15		86	81.2	91.2	89.4	62	88.7
20		75.7	73.2	83.9	81.2	41.6	78.6
Boeing							
5	98.6		99	99.5	99.4	97.3	97.8
10	94		95.5	89	95.7	89.8	92.2
15	86.6		89.5	82.8	83.5	73.2	73.3
20	75.2		81.9	70	66.8	53.5	57.5
HNet							
5	97.2	98.2		98.4	98.3	97.4	98.4
10	90.5	92.7		93.8	93.2	89.8	93.6
15	82	83.8		87.2	85.2	78	86.4
20	71.6	73.1		79.4	75.2	63.7	77.4
Virgo							
5	99.2	99.4	99.6		99.3	97.7	100
10	97.2	98.7	98.2		97.9	91.7	97.9
15	93.8	93.2	96.3		95.3	83.5	97.1
20	89.4	87.9	94.3		93	73.5	93.3
Hlink							
5	97.7	99	97.9	99.3		98.8	99.4
10	91.1	93.8	92.6	96.9		93.7	97.5
15	80.8	81.8	84.6	93.4		82	92
20	68	64.9	76.2	87.7		71	88
KuBs							
5	96.7	98.7	97.3	98.9	99.6		97.7
10	87.8	95.8	91.4	94	97.2		92.7
15	75	90	84	86	93		85
20	60	80	76	76	86		75

Pentriad							
5	98.4	95.7	98.6	87.9	99.3	96	
10	91.1	88.9	94.2	63.3	97.5	84.6	
15	83	72	87	48	94	63	
20	65	60	78	35	86	33	

Table 2

The results above indicate the actual Home Zone burden for an NGSO operator, because they provide the percentage of time the operator's serving satellite is close to another constellation. Again using the example of the HLink and Boeing constellations, although a Home Zone situation occurs 24.5% of the time, events would actually affect the use of the highest elevation satellite in the Boeing system only 100-95.7 = 4.3% of the time.

Home Zone Events Involving More Than Two Systems

Simulations have been run to assess the case where 3 and 4 systems fall under the Home Zone situation.

The first set of simulations used the Boeing, HLink and Pentriad systems. The "worst-case" simulation employed the assumptions used in the two-system simulations in Table 1 above. That is, it computed all Home Zone events. The "representative case" simulation employed the assumptions used in the two-system simulation in Table 2 above. That is, it computed only those Home Zone events in which the satellites are actually serving the same area. It is assessed in the Boeing system reference.

Results are given in percentage of time there is a Home Zone event involving all three systems, for 5, 10, 15 and 20 degrees of angular separation.

Angles	5	10	15	20
Worst-case	0.026	2.0	10.1	23
Representative case (from the Boeing perspective)	0	0	1.5	12.0

A second run has been done with the Boeing, HLink and HNet systems.

Angles	5	10	15	20
Worst-case	0.072	1.0	10.7	15.3
Representative case (from the Boeing prospective)	0	0.13	1.6	5.9

A third run has been done with the Boeing, Pentriad and HNet systems.

Angles	5	10	15	20
Worst-case	0.20	1.9	8.0	13.4
Representative case (from the Boeing prospective)	0.037	0.20	3.2	8.5

A fourth run involved the Boeing, Pentriad, HLink and HNet systems:

Angles	5	10	15	20
Worst-case	0	0.12	3.1	9.5
Representative case (from the Boeing prospective)	0	0.0001	0.17	2.3

The results indicate that, whatever the aperture angle, the occurrence of situations involving more than 2 systems will be quite limited.

The spectrum arrangements that would govern this specific case are the same as in the 2-systems case. Systems could either find a harmonious solution that satisfies all the parties or share the burden by dividing the available spectrum in thirds. No additional difficulty is therefore envisioned.

Implementing "Home Zone"

The Home Zone Cone Aperture

General Considerations

The selection of the Home Zone aperture angle will impact the quality of the links, the complexity of the systems, and their commercial viability.

The aperture angle shall be large enough to protect systems from harmful interference.

At the same time, a large aperture angle adds system complexity due to the strong impact on the operation of the systems. Potentially, it could even mean a reduced capacity if the Home Zone requirement overwhelms the system flexibility and thus obliges the system to operate with reduced spectrum.

The economic factor also must also be taken into account. While a large aperture angle better protects the links, it also leads to more complex system operation and possibly reduced capacity. On the other hand, a smaller aperture angle could put in jeopardy the availability of the links and thus the business model for the system.

The FCC applicants propose to operate different types of systems. Therefore, in view of their individual systems characteristics, each could have a different idea of what the proper value of the Home Zone aperture angle should be.

A system with a lot of satellite diversity capability may prefer a solution with a large angle to protect its links, knowing that it could employ its diversity capability to deal with the greater number of Home Zone events. At the same time, another system with a stronger budget link may prefer to have a smaller aperture angle to limit the complexity on its system.

From the FCC perspective, the selection of the proper aperture value will result from a balance between two paradoxical objectives mentioned in the introduction. The default scenario should at the same time (1) be an incentive for systems to coordinate (by making them "equally un-happy"), and (2) avoid undue constraints on the economic viability of the NGSO systems. In short, this aperture angle should make operators unhappy enough to encourage them to coordinate, but not too unhappy by putting their business in jeopardy.

In the end, the decision of the aperture value will necessarily be somewhat arbitrary. The choice should of course be backed by technical assessment of the degradation of the links as well as the impact on the systems operation. However, due to the great differences among the systems, there will be as many "suitable" values as applicants. Thus, there will not be an exact value, but an array of values, that will more or less satisfy the systems.

It is important to understand that the need for an arbitrary decision in this regard is inevitable. The significant differences between the systems means that a "perfect" value simply cannot be derived. A parallel may be drawn with the selection of an interference criterion for the NGSO systems. All the operators have different

approaches for defining the proper interference criteria needed to protect their systems. In that case also, a somewhat arbitrary value must be chosen to move the process forward.

With the above in mind, an angular aperture of 10 degrees might appear appropriate, because it protects against interference in the main beam of a victim receiver. At the same time, it defines a rather large zone where Home Spectrum would apply, and therefore still provides an incentive for the systems to coordinate. It also establishes a boundary on the protection that will be afforded to each system, preventing system operators from defining overly constraining protection needs for their systems.

Overpowered Systems

As noted above, a value for the Home Zone aperture has to be selected to sufficiently protect operations of NGSO systems without debilitating any system. This value would be the same for all systems, under the assumption that the operating NGSO systems have comparable power flux densities.

The downlink emissions of all NGSO systems in the Ku-band are governed by the EPFD limits of Article S22 and Section 25.208 of the Commission's rules. Because $EPFD_{down}$ is measured at the input of the GSO Earth station antenna, the flux on the ground of all the concerned systems will be of the same order of magnitude. Therefore, the proposed Home Zone angle should be adequate for all systems.

On the uplink path, however, the altitudes of the satellites are very different. Some are LEO and MEO constellations, while others employ Highly Elliptical Orbits over 30,000 km in height. This results in a widely dispersed range of e.i.r.p. for the Earth stations. Of most concern, the common angle defined for the cone aperture might be too small to protect LEO and MEO systems from the very high e.i.r.p. of the HEO Earth stations.

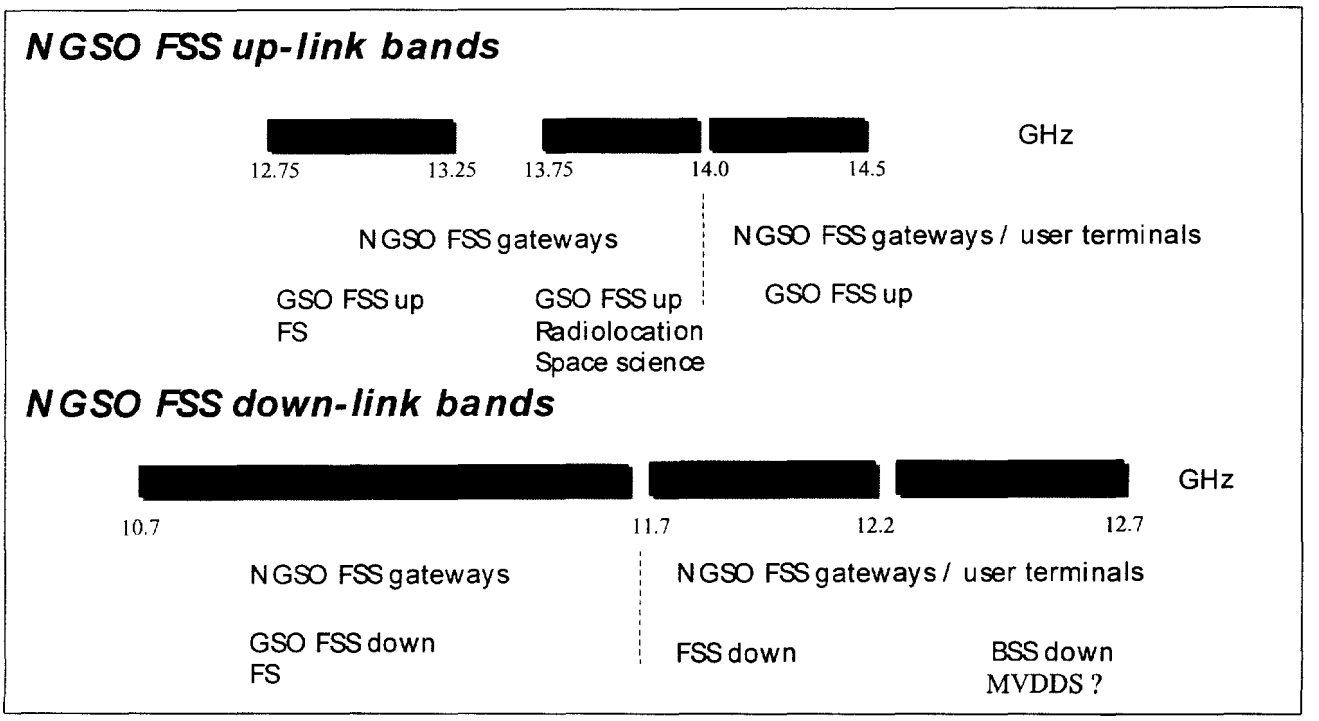
In such cases, several possible scenarios are possible. The simplest one would be for the HEO to readjust its e.i.r.p. to fall within an acceptable range.

Another alternative is to adopt a wider aperture angle for the more powerful systems. With this wider angle, the operation of the lower-power systems would be protected and all other principles of the Home Zone concept would remain applicable. This angle would apply to all systems, whenever one of the systems involved in the Home Zone event was a HEO system. At all other times, the smaller angle would be used.

Spectrum Arrangements

The segments of Ku-band spectrum available for NGSO systems are not all alike. All portions of the available spectrum are already used for different services. As a result, the constraints on NGSO FSS operation in each of these bands differ significantly, and the band segments are therefore not fungible.

The following chart shows the accessible spectrum and the different sharing regime in each part of the frequency bands:



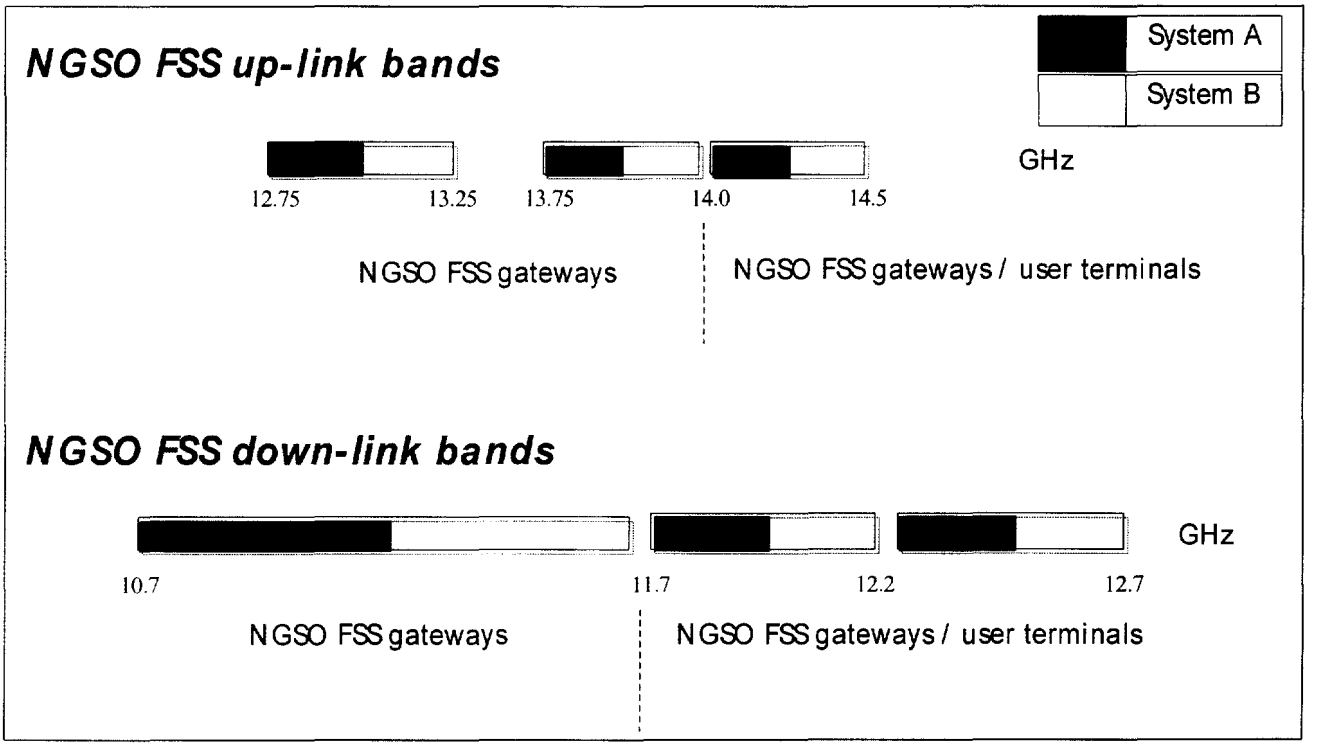
In a spirit of equality, whatever final solution the FCC adopts, it should provide each NGSO system equal access to bands with reasonably the same sharing conditions. In

other words, each system should have equal access to each of the following 6 band segments:

- 10.7-11.7 GHz, 11.7-12.2 GHz, 12.2-12.7 GHz for the downlink;
- 12.75-13.25 GHz, 13.75-14 GHz, 14-14.5 GHz for the uplink

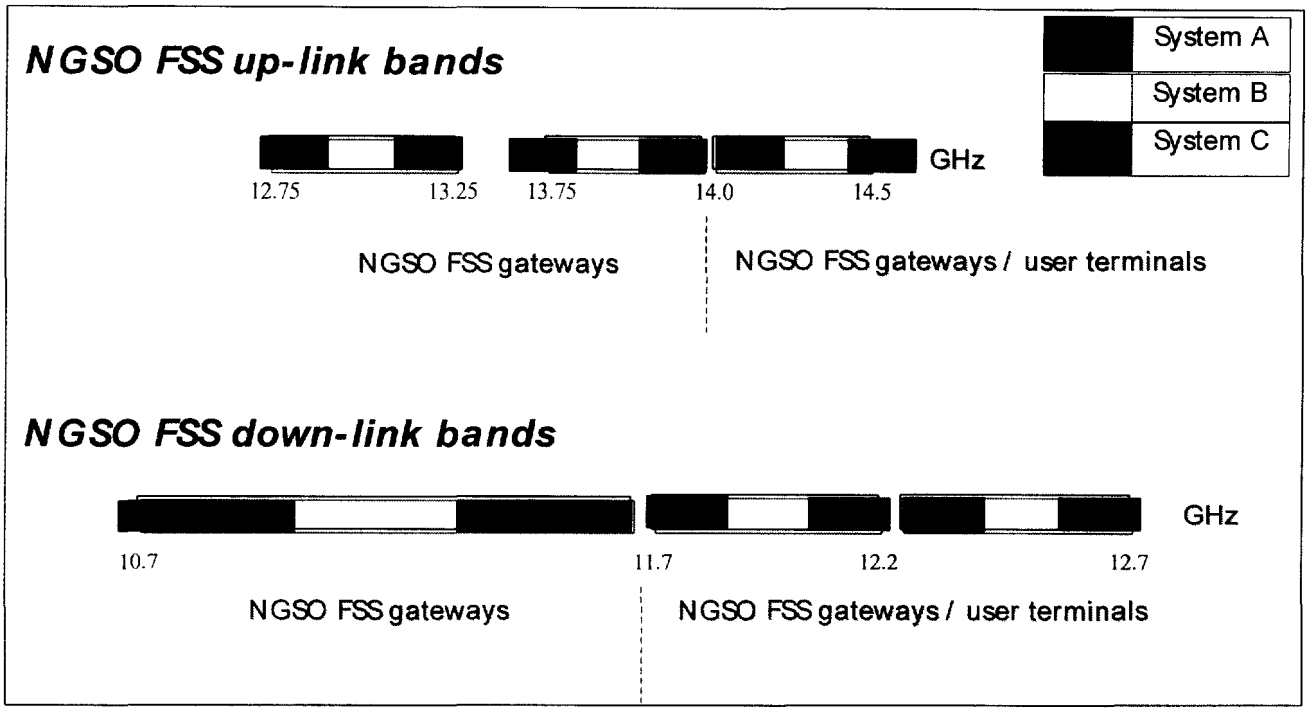
With the Home Zone solution, whenever the satellites of two different constellations are outside each other's Home Zone, each has access to the entire spectrum. In such case, there is no need to define additional sharing schemes.

However, whenever a satellite of an NGSO system is in the Home Zone of another constellation's satellite, the spectrum has to be divided in two parts.



Of course, such sharing can be tailored to better fit both systems if coordination succeeds. The solution given in the above chart would be the default scenario. It guarantees equitable access to equivalent spectrum for the two affected NGSO systems.

In the improbable case of three satellites of three different NGSO systems in the same Home Zone, the following sharing plan could be used as default. This plan assures equal access to spectrum for the three NGSO systems.



It must be noted that with publicly available data and software, the orbitography of each system can be determined with high precision. This means that no coordination is necessary between the NGSO systems in order for each to determine precisely when it is entering into another NGSO system's Home Zone and must therefore confine its transmissions to its Home Zone spectrum.

Furthermore, measurement techniques have been adopted by the ITU-R that enable operators to assess with good precision the level of signal generated by an NGSO constellation into a GSO network. If necessary, these techniques can also be used, with minor adaptations, by an NGSO operator, to prove whether another NGSO operator is respecting its Home Zone spectrum.

All the tools are therefore available for the Home Zone solution to be implemented as a default solution, whenever NGSO systems are unable to reach a coordination agreement.

It is a default solution GUARANTEEING an EQUITABLE access to ALL the proposed NGSO systems.

Finally, it should be noted that the splitting plan for the available spectrum could be amended by the Commission to take into account individual NGSO systems needs and preferences.

Conclusion

While coordination is the optimal method for NGSO/NGSO sharing, the Commission needs a simple default solution that will govern sharing among systems that, for whatever reason, are unable to reach successful coordination agreements. The Home Zone concept provides such a solution. It is an enhancement of the Home Spectrum approach, but goes one step further to take advantage of the directivity of the antennas in the Ku-Band. A default sharing regime based on the Home Zone approach can be clearly and fully defined in only a few simple rules. The resulting regime will not require the FCC to micro-manage the licensees or revisit the regime as new systems are deployed.

With the Home Zone approach, most of the time, each system can operate over the entire spectrum without high levels of interference to or from other constellations. The Home Zone solution therefore provides much greater flexibility and capacity for all of the systems than the Home Spectrum approach.

Moreover, the Home Zone approach provides each of the NGSO FSS systems equal access to the spectrum. However, it avoids the need to permanently allocate non-fungible frequencies among the applicants. It can be applied in a completely generic manner, without taking into account specific system characteristics. This is the key to regulatory certainty. The Commission can be assured that, in the event that a coordination agreement cannot be reached for any reason, a simple sharing mechanism, that is relatively impervious to dispute, is in place to permit entry of all qualified applicants.

The Home Zone solution also provides two important incentives to operators. First, while it undoubtedly imposes less of a constraint on each NGSO FSS system than the Home Spectrum approach, it nevertheless provides a

strong incentive to coordinate. Any rational operator desiring to optimize use of its constellation would prefer a coordination process, as good faith coordination can lead to a more efficient solution, "customized" to the design of the given systems.

Finally, the Home Zone solution allows each system to cope with the sharing burden in its own way. As shown in previous documents, systems that have certain flexibilities can employ the entire spectrum most of the time. The cost of incorporating this flexibility in the system is therefore balanced by a tangible benefit. Less costly systems that chose not to implement flexibility can still optimize their systems to operate on their reserved part of spectrum under the Home Zone approach. This ability given to systems to individually optimize their operation makes the Home Zone solution the most economically viable.

In sum, the Home Zone approach could be used by the Commission to license the competing Ku-band NGSO applications in a spectrum efficient manner that takes into account the abilities of these systems to operate co-frequency a great portion of the time. While this default solution guarantees that each licensee will have equal access to the spectrum once its system is launched, it also preserves the opportunity to reach more efficient sharing agreements with other operating systems, if desired.