* * *

In conclusion, UTC urges the Commission to commence a proceeding to amend Parts 2 and 101 to permit shared, secondary terrestrial fixed service use of the 14.0-14.5 GHz band for critical infrastructure industry communications. By adopting the requested rules, the Commission will address the critical lack of CII spectrum and better enable CII entities to build more efficient networks and respond during emergencies.

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classes or groups of licensees within a service.").

Respectfully submitted,

UTILITIES TELECOM COUNCIL

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Sharing Frequencies for FSS and FS Services in the 14.0-14.5GHz Band

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

RKF Engineering Solutions, LLC, is a Washington DC based engineering consulting firm which has been involved in communications engineering for over twenty four years. The company provides consulting services in satellite communications, terrestrial communications, cellular communications as well as related areas.

RKF was engaged to assist in locating spectrum for the implementation of critical infrastructure Fixed Service (FS) facilities in order to allow expansion of their present operations. Critical infrastructure communications are needed for utilities, pipelines and transportation systems. These links have to be highly reliable (99.999%). One of the more common applications includes supervisory control and data acquisition remote terminal units (RTU) to centralized operations centers. These are the systems that automate and centralize the monitoring, control, and alarming of remote equipment. In order to support these application both point-to-point (P2P) and point-to-multipoint (P2MP) systems are needed, with fixed and temporary terminals.

We have examined the existing frequency band allocations for both non-Federal and Federal services and have determined that the 14.0-14.5 GHz band, the present home of the Fixed Satellite Service (FSS) earth-to-space operations, can be shared with the FS without causing harmful interference to existing links operating in that band as well as secondary services and, with a few minor exceptions (e.g., TDRSS and RSA which would require stay-out provisions). Furthermore the band can be shared with existing services without undue burdens placed on the new FS services.

Our simulations demonstrate that the band can be shared with the FSS and that at least 376,000 FS links can operate without causing harmful interference.

Our analysis of how new FS stations would operate without being adversely affected by existing users revolves around use of digital technologies, especially Orthogonal Frequency Division Modulation (OFDM). OFDM has been well recognized as a means for overcoming a multipath setting by separating a high data rate signals into a parallel transmission of low data rate carriers. OFDM allows the FS to take advantage of Fast Fourier Transform (FFT) technology, a simple low complexity approach for high data rate applications. As detailed in Section 3, our use of these methods will permit FS users to operate in substantially all locations. Where interference levels are high, desired sites can be relocated.

Careful and ongoing coordination with existing and future users of the band is an essential component of the proposal. Such coordination would at once comply with existing coordination rules and go beyond the traditional coordinator's role. A central coordinator (the "CII Coordinator") would be responsible, among other things, for

reaching necessary coordination agreements to protect TDRSS and other governmental uses of the band, to be updated as necessary as government operations change and develop over time, for establishing a uniform transmit and receive frame structure and a centralized clock for frame synchronization by individual stations, and for monitoring the base station deployments and temporary fixed terminals to enforce restrictions designed to prevent harmful interference into the geostationary satellite arc and other services.

1 Analysis of Domestic Allocation Table

The study to locate spectrum where non-Federal-Government fixed services could be implemented has required that we examine all existing users in the 14.0-14.5GHz band. Once the potential interference can be mitigated, the new service can be allocated and service rules developed to permit an FS service to begin operation. The principal advantage of sharing with the FSS Ku-Band uplinks is the limited number of services that operate in that band. While the FSS earth-to-space service is heavily occupied by existing transmitters, other services are few and can be accommodated.

1.1 Services Presently Allocated in the 14.0-14.5 GHz Band

FCC Rules CFR 47 Pt 2.106 Table of Allocations indicate that service assignments in the band are allocated domestically for both Government and non-Government use. The table further indicates that the 14.0-14.5 GHz band is subdivided and the subdivisions are different for both users. Publicly available Government (Defense, NTIA, and FAA) and Non-Government (FCC) data bases were investigated to determine actual facilities use in the band.

In Regions 1 and 3, the bands 14.3 – 14.5 GHz are allocated on a co primary basis to Fixed, FSS uplinks and Mobile except aeronautical mobile services. Given that these Regions have these co primary allocations indicates that permitting Fixed service on secondary basis to FSS operations in the 14.0 – 14.5 GHz band is feasible. This secondary Fixed service allocation in the 14.00 – 14.5 GHZ band will permit services that are more in harmony with the services permitted in other Regions.

1.2 Primary Service Users in the Band

A review of Pt.2.106 Table of Allocations indicates that the only primary service license holders in the full band are earth-to-space FSS licensees which can occupy the entire 14.0-14.5 GHz band. The FSS is populated primarily by VSAT users, who most often operate pursuant to blanket licenses with up to 50,000 users per grant. The current number of license grants exceeds 500,000 (potential) VSATs.

1.3 Secondary Service Users of the 14.0-14.5GHz Band

14.0 – 14.5 GHz

The mobile satellite service (Earth to Space) is allocated on secondary basis throughout the 14.0 – 14.5 GHz band. These mobile satellite services use geostationary FSS satellites

and comply with the technical requirements for VSAT operations to avoid adjacent satellite interference.

14.0-14.2GHz

Space research services presently operate in the sub-band 14.0-14.2GHz band on a secondary basis and must be protected. The only presently non-FSS facilities in this band are NASA's Tracking and Data Relay Satellite System (TDRSS) facilities in White Sands, New Mexico. There are plans to locate a second TDRSS site in Maryland which must also be protected. At present, the protection plan for the TDRSS site(s) is a 125 kilometer protection zone where no CII transmit stations would be located. We recognize that NASA has TDRSS facilities in Guam, however CII companies are not likely to operate in that area.

Other NASA research stations that may be operating in this band over time will be coordinated in accordance with CFR 47 Pt101.103 prior to operation as described in Sec. 101.103 Frequency Coordination Procedures of PART 101_FIXED MICROWAVE SERVICES, TITLE 47—TELECOMMUNICATION CHAPTER I--FEDERAL COMMUNICATIONS COMMISSION.

14.2-14.4GHz

The MS service is currently allocated as secondary in this band[1]. MS operations have been carried under the LTTS allocation as described in Part 101 of the Commission's rules. The TV pickup trucks which have operated under the LTTS allocation to our knowledge are no longer in operation. If there are remaining stations, these will be coordinated in the areas where they operate.

14.4-14.5GHz

The Government has a limited number of secondary fixed and mobile allocations in this band. For the FS point-to-point stations, CII Coordinator will coordinate with existing stations by insuring that no interference will occur through the use of proper frequency selection, CII Coordinator carefully selected facility locations and the analysis of the technical specifications of each station in the manner of standard microwave link coordinations.

Regarding mobile aeronautical stations, land based aeronautical stations, land mobile stations, and surface telemetering mobile stations which may exist, each of these facilities can be coordinated with CII's planned FS service after the CII Coordinator is provided with frequencies used, locations of operations identified and technical details are made available that allow coordination to occur. In this regard, the CII coordinator will interact with US Government agencies to coordinate any future Government operations in this band.

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[1] Title 47 Section 101.147 Footnote 24

The CII Coordinator will coordinate sharing with mobile stations in this 100MHz band using interference avoidance techniques such as cognitive radio to sense the spectrum and avoid frequencies being used by mobile operators in the area.

Cognitive radio is a new technology with several challenges. The FS radios require knowledge of the mobile terminal interference threshold, and must sample fast enough and accurately enough to avoid the interference. A cooperative scheme could be implemented and provide the necessary accuracy. Each fixed terminal would sense the environment and report their measurements to a central controlling entity. Based on measurements from many fixed stations a coordination area could be maintained, which would avoid using the affected frequency.

The Radio Astronomy Services (RAS) which operate in the 14.47-14.5 GHz band will also be protected. Exiting RAS facilities can be coordinated by establishing exclusion zones which will provide protection to the geographic areas where such stations are located.

2 Method of Operation of CII Service

Critical infrastructure communications are needed for utilities, pipelines and transportation systems. These links have to be highly reliable (99.999%). One of the more common applications includes supervisory control and data acquisition remote terminal units (RTU) to centralized operations centers. These are the systems that automate and centralize the monitoring, control, and alarming of remote equipment. In order to support these application both point-to-point (P2P) and point-to-multipoint (P2MP) systems are needed, with fixed and temporary terminals.

CII stations would use a channelization plan for the 14.0-14.5 GHz band based on time division duplex (TDD) operation. TDD operation requires that the transmit channels for both ends of a link use the same frequency. This has several advantages. Unlike frequency division (FDD) operation, no duplexer is required. Furthermore, since uplink and downlink channel characterizations are reciprocal users could employ smart antenna technologies such as beamforming and nulling, which can be used to reduce intersystem interference.

Current standards such as 802.16e (WiMax standard for mobile operations) propose TDD operation with channels up to 20MHz. This or other channelization plans could be selected for this band. The CII Coordinator would develop a uniform channelization plan including a uniform transmit and receive frame structure. The CII Coordinator would supply an accurate clock to both stations for frame synchronization. Time synchronization of transmit and receive stations will minimize interference among CII stations.

The proposed new 14 GHz CII service will be required to avoid harmful interference to FSS/MSS uplinks.-The proposed interference threshold, at the satellite, is I/N = -12.2 dB[2].

ITU radio regulations currently exist that limit interference into FSS uplinks. The EIRP from any terrestrial station is limited to 45dBW and terrestrial microwave transmitters must point at least 1.5 degrees away from the geostationary arc. This means that any transmit terminal cannot point within 1.5 degrees to any possible geostationary satellite at any longitude. If such a case does occur then it is incumbent upon the installing team to change the pointing direction of the transmitter. Assuming that transmit and receive site locations are fixed, a second hop could be added between the transmitter and receiver to ensure that none of the transmitters is aimed at the geostationary arc.

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[2] The ITU Radio Regulations in Appendix 5, Table 5-1 "Technical conditions for coordination" for the band 14.0-14.5GHz, remarks that for networks for which the value of $\Delta T/T$ is greater than 6%, i.e., I/N = -12.2dB, coordination is required. ITU rule is used because no rule exists in the Part 25 of CFR 47 accept as noted in 25.253 (3) where ATC is described and $\Delta T/T$ of 6% is used as a maximum level of interference to other MSS systems..

The new proposed FS service will support fixed point-to-point services, and point-to-multipoint services, with both fixed and temporary fixed terminals (TFTs). In order to facilitate the use of smaller terminals and to provide additional interference margin to the FSS, the proposed requirements are based on having the terminals point at least 5 degrees away from the geostationary arc. The maximum terminal EIRP is limited to 28 dBW/MHz or 45 dBW/50 MHz.

The following requirements are proposed for fixed point-to-point (P2P) services and for terminals used in point-to-multipoint (P2MP) systems.

1. The stations shall off-point at least 5 degrees away from the geostationary arc
2. Antenna diameters shall be 45 cm or greater
3. Power control shall be required on all links in order to minimize excess margin
4. The maximum EIRP is 28 dBW/MHz per station

The following additional requirements would only apply to P2MP BSs.

1- The fixed base station shall have a minimum antenna gain of 17 dBi and off-point at least 5 degrees from the GEO arc.

2- The maximum transmit power of a base station shall be 11 dBW/MHz

3. Mitigating Interference to the FSS/MSS Services

A study was performed to determine constraints (number of simultaneous transmissions, maximum transmit power, dish size and GEO arc exclusion angle) required to allow the new terrestrial service.

Simulations were executed to determine the interference at the satellite for a Point-to-Point (P2P) deployment of terminals, and a deployment of Base Stations (BS) providing Point-to-Multipoint Services (P2MP) to Temporary Fixed Terminals (TFTs). The P2P terminals are assumed to be pointed towards each other, the BS terminals are assumed to transmit to a set of TFT terminals, and vice versa.

A worst case estimate of the number of terminals that can transmit simultaneously, without violating ITU[1] interference restrictions at the satellite (i.e., I/N < -12.2dB), are shown in Table 3-1. The simulations show that at least 376,000, simultaneously transmitting, P2P terminals can be deployed over CONUS. This is the limiting case for any arbitrary deployment of terminals that operate according to the rules defined in the previous section. These numbers are large enough to present little practical concern.

The simulation results are based on a 5 degree exclusion angle, terminals (P2P and TFT) with 0.45m dish diameters and BS's using antennas with 17 dBi gains. P2P links were varied up to 20 Km. Azimuth and elevation angles were selected randomly with the maximum elevation angle restricted to 30 degrees. P2MP cells were varied up to 10 Km.

In the P2MP simulation the BSs were setup to provide coverage only to the south so that the TFTs had to point north. This is an example of an approach that the CII Coordinator can use to ensure that TFT terminals off point from the geostationary arc by more than 5 degrees. Other workable approaches are discussed in Section 3.2 below.

	# of Simultaneously Transmitting Links per 50 MHz
P2P transmitting terminals	376,000
BS transmitting terminals	873,000
TFT transmitting terminals	1,350,000

Table 3-1. Summary of Worst Case Analysis and Simulation Results (number of supported terminals transmitting simultaneously without exceeding interference limits at the satellite). The above results assume dedicated use per category

Test satellites were placed at 60°W, 95°W, and 135°W longitude. The 60°W satellite was chosen because it has low elevation angles (<20°) to the West Coast. The 130°W satellite, has low elevation angles (<20°) to the East Coast. These satellite locations can see the entire CONUS area. The east coast elevation angles to 135°W and the west coast elevation angles to 60°W are within the 0-30 degree elevation angles assumed for antenna pointing of the point to point terminals. Therefore, the coastal stations for these satellite locations reflect the worst case in terms of interference toward the satellite for the point to point simulations. Point-to-point terminals are the bounding scenario that cause the most interference to geostationary satellites for a given number of terminals. Lastly, the 95°W satellite was chosen because it is at a midpoint between the first two satellites. All three of these satellite locations are in view of the entire CONUS area.

Input power to the terminal antennas was calculated so that each link is closed with a C/N value of 15dB (in the calculation of N, noise temperature is assumed to be 290K). A 15 dB C/N is sufficient to support a 16 QAM service.

Each simulation was run for 1,000 trials and the results presented correspond to the worst case interference from those trials. During the simulations it was required that the I/N at the satellite was less than -12.2dB as described in footnote 1 (noise temperature at satellite is assumed to be 600K). This causes the noise floor of the satellite uplink to increase by 0.25 dB. This level is consistent with the maximum allowable interference levels given in ITU-R SF.558.2. All simulations were run enforcing a 5 degree exclusion angle to the geostationary arc.

3.1 Power Control

The FS terminals would be required to use power control so that links close with minimum margin. The aggregate interference at the satellite is then a function of the distribution of terminals, the distance between the transmitter and receiver, and the fade conditions experienced by each terminal. To analyze the interference we considered a uniform grid of terminals over the CONUS. The points were separated so that fade conditions were approximately uncorrelated. For both P2P and P2MP simulations the transmitter was centered at each grid point and the receiver is uniformly varied over circles with radii of 1, 3, 5, 10, and 20 Km, depending on the chosen maximum link length.

Worst month fade levels were calculated using ITU-R P.530-11 for both rain and multipath conditions. A double integral was required to determine the average worst month fade: The first integral was over all link distances and the second integral was over the link availability from 0 to 99.999%. For each availability, the maximum of clear sky and rain fade levels was selected. Generally, the rain fade level dominated the link.

Finally, the average worst month fade level was found by averaging the results from each grid point over the country. This yielded an average worst month fade of 1dB for links up to 10km, and 2.7dB for links up to 20km. The worst month average fade for cells of radius 1, 3, and 5 km were found to be far less than 1dB.

The above result yields a good temporal statistic of the expected fade level and therefore power control level required for each link in a large distribution of links. However, it is not a spatial statistic. Spatially there maybe storms covering large areas and high fade conditions may result over portions of the coverage area. In order to investigate the spatial statistics, rain accumulation data from NASA's TRMM satellite was examined. Figure 3-2 shows an example of rain accumulation averaged over 3 hours.

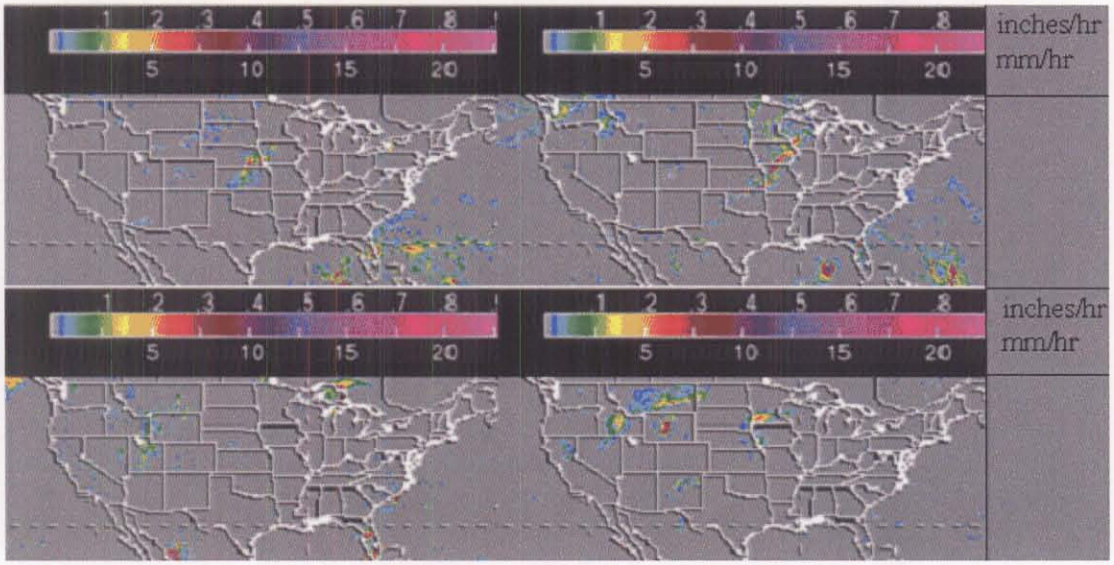

Figure 3-2. Rain accumulated over 3 hours

We found that even severe weather events usually cover less than about 3% of country. Furthermore, we notice that fade statistics averaged over 3 hours show accumulations less than 10 mm/hr. However, severe rain events show much higher accumulation rates. Figure 3-3 shows 99.99% rain rates for the US. Florida has rain rates on the order of 100 mm/hr. The intense rain is caused by small fast moving rain cells (3 to 5 Km in diameter). The intense rain typically lasting less than 10 minutes. Thus the intense rain covers a much smaller area than the accumulated coverage shown in the TRMM data averaged over 3 hours.

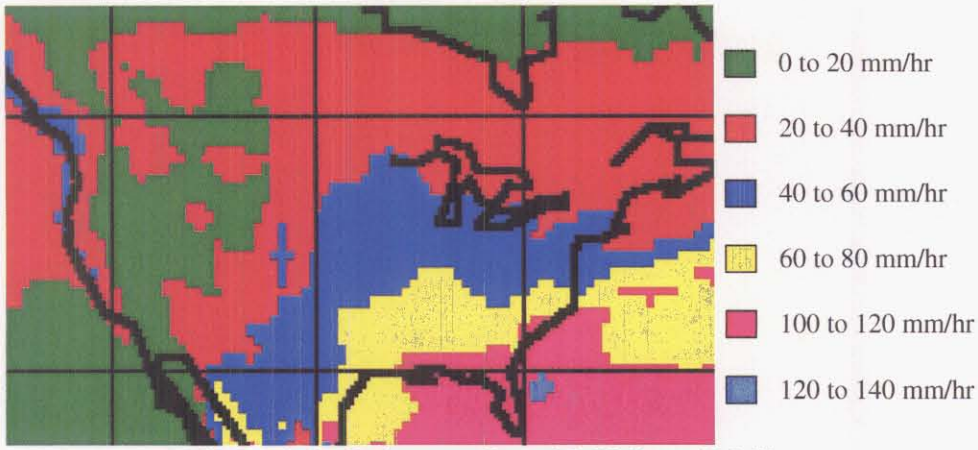

Figure 3-3. Rain rates for a 99.99% availability

In order to overbound the spatial distribution of rain we selected the 3% of the country in the worst rain regions and assumed those areas had 99.999% fade conditions. The worst rain area is shown shaded in Figure 3-4.

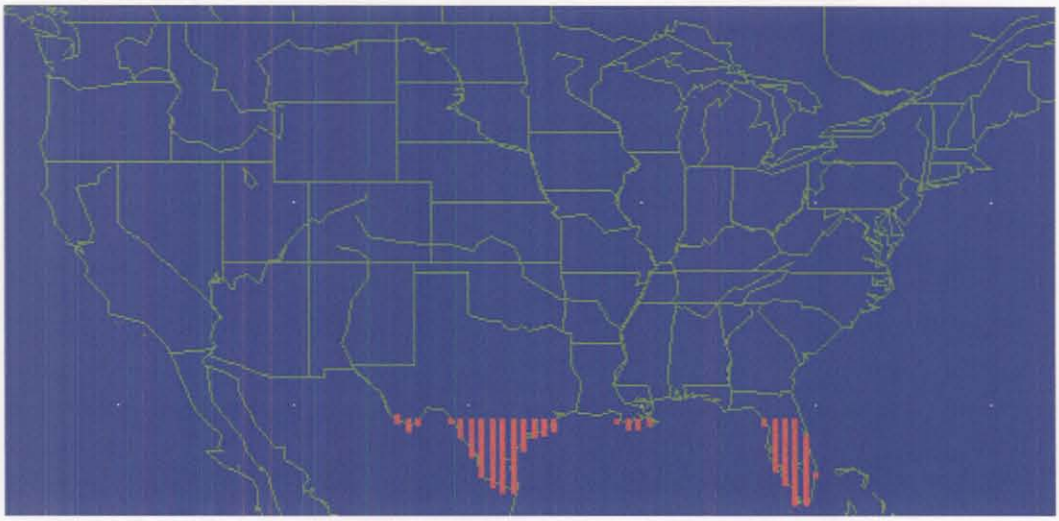

Figure 3-4: 3% of CONUS with the worst rain fade

With 3% of the country in 99.999% fade and the rest having an average worst month fade, the average power control level is then approximately 19.57dB for 10km radius cells and 32.13dB for 20km radius cells.

In the simulations, we do not assume that the interfering signal which reaches the satellite is attenuated due to rain. This is a worst case assumption and results in a lower bound on the number of terminals supported. As a practical matter some attenuation on the satellite path does normally occur.

3.2 P2P Terminal

The P2P antennas were modeled according to ITU F.1245, which is representative of what is chosen in practice. The P2P terminals were placed randomly throughout CONUS. It was assumed that each P2P terminal communicates with another one that is placed at random within a 20km radius. Each link is assumed to have sufficient power to close the link. The gain of the satellite antenna was assumed to be 31dB, which is typical for CONUS coverage. It was assumed that each P2P terminal had an elevation angle which was uniformly distributed between zero and thirty degrees. This is also a worst case assumption since most terminals should be pointed about horizontally. In addition, each terminal's bore sight was given a random azimuth orientation.

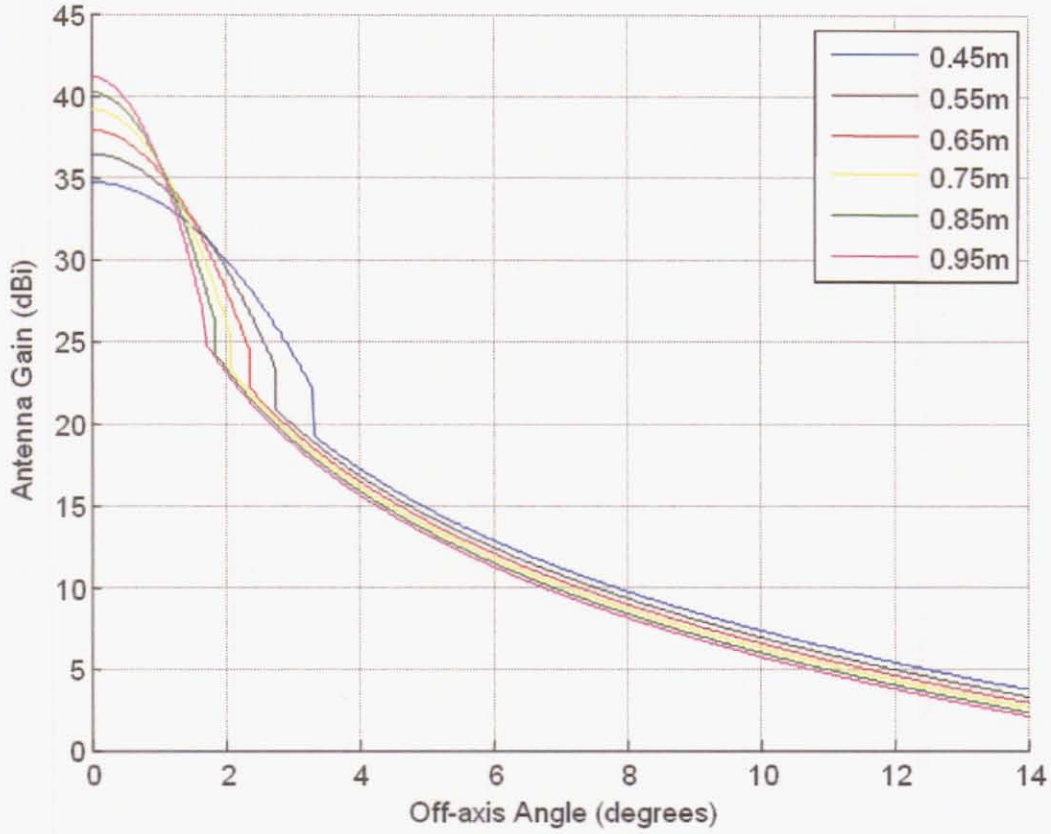

Figure 3-5. P2P antenna approximate radiation pattern for different dish diameters, based on model ITU F.1245. Assuming antenna efficiency of 0.65.

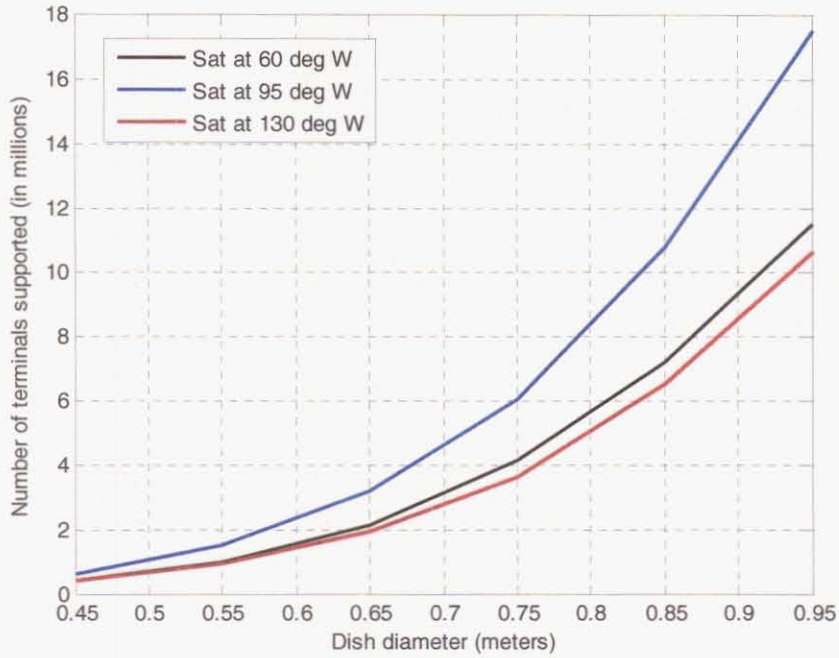

Figure 3-6. Maximum Number of P2P Terminals Transmitting Simultaneously, assuming transmit power which closes the average link.

Figure 3-6 depicts the maximum number of terminals that can operate simultaneously as a function of antenna dish size (for diameters of 0.45m - 0.95m in increments of 0.1m). From Figure 3-6, even for the smallest dish size considered, the maximum number of P2P terminals which can transmit simultaneously is 376,000 (for the worst case satellite, 130°W). As shown, the potential for interference to a satellite operating in the middle of the geostationary arc at for example 95°W is less than the other two orbit locations (60°W and 130°W).

A 20 Km link in Florida, operating in a 99.999% fade, using 45 cm receive and transmit antennas would required an EIRP ≅ 48 dBW. In order to be consistent with ITU rules a maximum EIRP equal to 45 dBW is proposed.

3.2 Mitigating Interference from TFTs

One function of the CII Coordinator will be to ensure that Temporary Fixed Terminals (TFTs) follow all the proposed FCC rules including off pointing at least 5 degrees from the Geostationary arc. There are several approaches that can be used to ensure that the TFTs avoid the geostationary arc no matter where they establish a communications link. Three examples are described as follows:

1. TFT installers could have a simple tool that tells them where to point or tells them where to point and indicates if they are allowed to point in a given direction.

2. A simpler method is for the base station to limit the directions where it points. For example if the base station points in a southerly direction then the TFT must point in the opposite direction away from the geostationary arc.
3. A combination of methods 1 and 2.

The CII coordinator will allow TFT base stations to operate only if an acceptable approach is utilized. The following sections analyze the interference impact of using method two alone to guarantee transmitter terminal pointing exclusion from the geostationary arc by 5 degrees or more.

3.2.1 Point-to-multipoint links (P2MP)

In the following scenario, base stations (BSs) are providing P2MP service to Temporary fixed terminals (TFTs). Depending on their location the TFTs may have high elevation angles toward the BS with geometries that could point into the geostationary arc. One way to avoid interference into the geostationary arc would be to have the CII Coordinator to establish operating constraints based on the GPS position of the BS and TFTs. The central station would be responsible for approving communications only if the TFT were pointed at least 5 degrees from the geostationary arc.

In the following simulation a different method of operation was adopted. The fixed base stations point only in a southerly direction such that the TFT has to point northerly. The reason for this pointing convention is that the TFT terminals have a high peak gain, and in some cases point upwards since the BS terminals are 30m tall. This method ensures that the TFT off-points from the geostationary arc by 5 degrees without requiring the TFT to check its position. Thus we avoid harmful interference to the geostationary arc. The cell coverage is assumed to be 10 Km or less. The BS will transmit a sectorized pattern that will point no more than θ degrees in azimuth from due south as shown in Figure 3-7, below. The value of θ is latitude dependent and is chosen so that the temporary terminal will point at least 5 degrees from the geostationary arc.

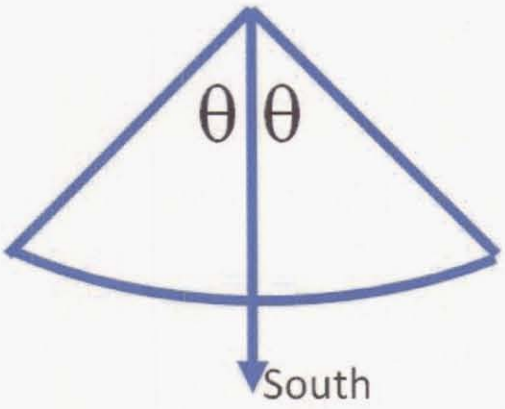

Figure 3-7. Fixed transceiver allowed pointing directions.