Interference from the Deep Space Network's 70-m High Power Transmitter in Goldstone, CA to 3G Mobile Users Operating in the Surrounding Area

Christian Ho
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California 91109
Tel: 818-354-9254; e-mail:christian.ho@jpl.nasa.gov

Abstract- **The International Telecommunications Union (ITU) has allocated 2110-2200 MHz for the third generation (3G) mobile services. Part of the spectrum (2110-2120 MHz) is allocated for space research service and has been used by the DSN for years for sending command uplinks to deep space missions. Due to the extremely high power transmitted, potential interference to 3G users in areas surrounding DSN Goldstone exists. To address this issue, a preliminary analytical study has been performed and computer models have been developed. The goal is to provide theoretical foundation and tools to estimate the strength of interference as a function of distance from the transmitter for various interference mechanisms (or propagation modes), and then determine the size of the area in which 3G users are susceptible to interference from the 400-kW transmitter in Goldstone. The focus is non-line-of-sight interference, taking into account of terrain shielding, anomalous propagation mechanisms, and technical and operational characteristics of the DSN and the 3G services.**

Keywords-interference; propagation; 3G, wireless; DSN, anomalous mode, diffraction;

1. Introduction

The International Mobile Telecommunications (IMT-2000), also known as 3G wireless, has been allocated 2110-2200 MHz for its mobile services [1,2,3,4,5]. Part of the frequency band has been used for space research services for many years. NASA is using the 2110–2120 MHz band for high power uplink transmissions at its Deep Space Network (DSN) facility in Goldstone, California. Thus, the 3G mobile receivers will likely experience interference in the 2110–2120 MHz frequency band when operating in the areas surrounding Goldstone. This study is going to develop a tool to model and simulate these interference effects.

The severity and duration of such interference would depend on many factors: the frequency channel assigned to the mobile unit, time of day, power of transmission at Goldstone, and orientation of the transmitting antenna. The interference intensity strongly depends on the terrain profile between Goldstone and the mobile unit, and weather condition in the area. At very small percent of time, the interference can propagate trans-horizontally through anomalous modes with little attenuation [6]. In order to assess the geographic extent of this potential interference, an interference contour map needs to be developed based on 1) characteristics of anticipated 3G mobile receivers, 2) the DSN antennas and high power transmitter, and 3) microwave propagation models, which includes terrain diffraction, atmospheric scattering, ducting and rain scattering.

In this study, we use the ITU propagation models to estimate the coordination distance around the Goldstone 70-m transmitter antenna by taking into account terrain effects [6,7,8,9,10]. Coordination distances are those at which the radiation levels from DSN transmissions are exceed the IMT-2000 permissible interference levels for a given percentage of time [6]. A computer software is developed to calculate the interference level along all azimuth directions from the transmitter [5]. Firstly we perform the terrain profile analysis to identify whether the path between transmitter and receiver is a line of sight or trans-horizon. The terrain diffraction loss is calculated through multi-mountain tops for each terrain profile. Then attenuations through two anomalous propagation modes (modes 1 and 2) after a terrain shielding correction are studied at a small percent of time. Finally, propagation losses through all modes are compared and the minimum loss at each direction is found out. Based on the loss, coordination distances are drawn around the DSN Goldstone station for 3G mobile users.

2. Propagation by Terrain Diffraction

2.1. Terrain around Goldstone Site: The DSN's Deep Space Station 14 (DSS-14) is a 70-m antenna located in the Mojave Desert, an area filled with bare hills and dry lakes. With an elevation of 1,002 m above sea level, the antenna is surrounded by hills on the southeast, west, and north sides. The hill elevations range from 1400 m to 1700 m. Figure 1 is a map showing the terrain elevation around the 70-m antenna. These terrains normally would prevent line-of-sight interference and would offer significant interference protection for the DSN and other users of the spectrum sharing the same frequency bands.

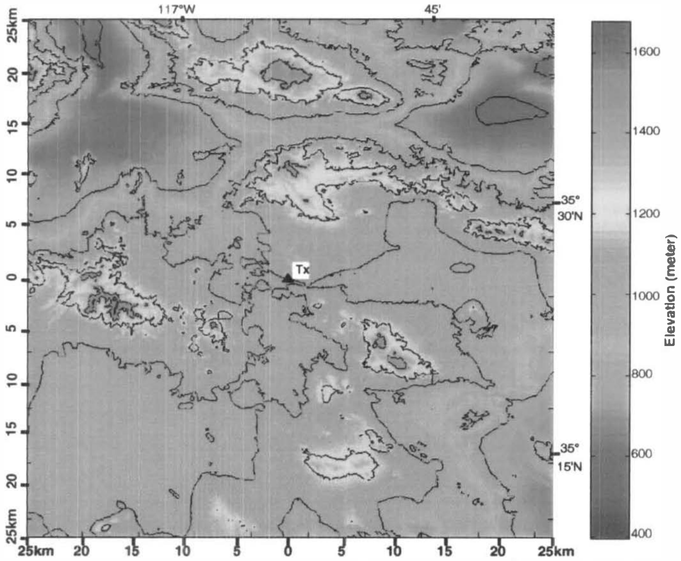

Figure 1. The terrain elevation around the Goldstone 70-m transmitter. The map is centered at the antenna (triangle mark) with each side 25 km extend. There are some small hills to the south side of the transmitter. There are some open areas nearby on the east and west sides, and a large mountain lies on its north side.

Two open valleys lie toward the east and northwest sides of the antenna. However, immediately to the south side of the antenna, there are two small hills with an elevation of about 1100 m, blocking the view of antenna with an elevation angle of ~2°. The surrounding terrain elevation angles have important effects on interference propagation through diffraction and ducting as we show later. Hills with larger elevation angles block the interference signals by increasing the attenuation of the propagation. Figure 2 shows the surrounding terrain elevation angles relative to the mechanical center of the 70-m antenna, which is about 37 m above the ground. A large mountain lies at the north side of the antenna with the maximum elevation angle of 4.8°. At the east and northwest sides, terrain elevation angles relative to the antenna are lower (1.0°–1.2°) due to open valleys. The antenna does not transmit signals when its elevation angle is less than 10°.

2.2. Diffraction Losses over the Terrain: The S-band interference signals can propagate beyond the line of sight through hilltop diffraction [10]. For the terrain diffraction calculation, we used the Goldstone–Los Angeles path as an example because a metropolitan area with a large community of 3G users is our major concern. The terrain profile from the Goldstone 70-m transmitter (Point T) to the downtown Los Angeles (L) along a 215° azimuth cut is shown in Figure 3.

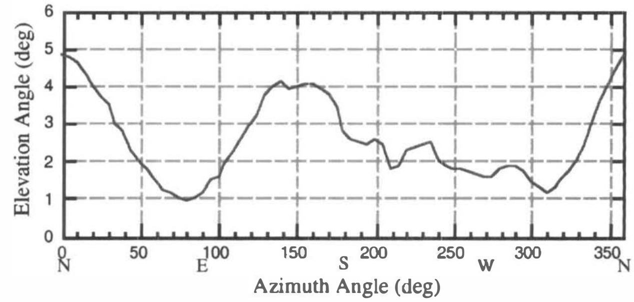

Figure 2. Terrain elevation angles relative to the center of the 70-m antenna at Goldstone.

The terrain elevation has been modified and plotted on a curved spherical Earth surface with a 4/3 Earth radius. We can see that on the left side there of Figure 4, there are several small hills in the Mojave desert highland. The high terrain of the San Gabriel Mountains on the Los Angeles side shields a large amount of any interference signals. We used a standard method [10], which ITU recommended, to calculate the diffraction losses from the transmitter T to Points A, C, E, G, and L as marked in the plot.

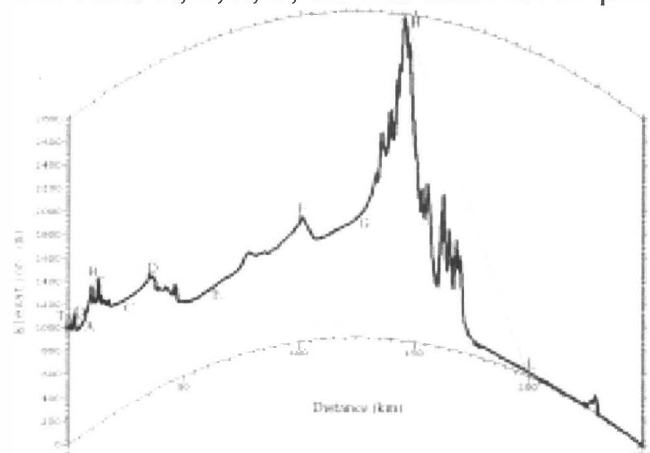

Figure 3. The terrain profile from the Goldstone 70-m antenna (left) to Los Angeles (right). This is a cut along the 215° azimuth angle relative to the transmitter site (0° points the north).

Table 1 lists all parameters and preliminary estimate of total diffraction losses from the transmitter over several hilltops to points A, C, E, G, and L respectively (as shown in Figure 3) along the Goldstone–Los Angeles terrain profile. The definition of all parameters can be found in reference [4]. Actual losses may be larger than those shown in Table 1 because most hills have rounded tops and rough surfaces, instead of sharp, knife edges. The rounded hilltops have additional curvature loss of 10–20 dB.

Table 1. Diffraction Losses over 215° Terrain Profile

Path	d, km	θ, 10^{-3}	v	J(v), dB	L_{df}, dB	L_{fs}, dB	L_d, dB	P_r, dBm
TOA	15	29.13	6.56	29.2	29.2	113	142.2	-72.2
TBC	25	49.33	14.59	36.2	36.2	127	163.2	-97.2
TBD	35	34.7	11.86	34.4	at E			
BDE	49	-0.71	-0.29	3.6	38.0	155	193.0	-126.8
TBF	101	25.79	10.47	33.3	at G			
BFG	111.5	7.4	3.8	24.4	57.7	162	219.7	-153.7
TBH	145	14.66	6.09	29.5	at L			
BHL	186.5	71.78	53.05	47.4	76.9	166	242.9	-177.3

Based on the preliminary results in Table 1, we can see that when the transmitter power is 20 kW, and the 3G receiver antenna gain $G_r = 0$ dB, the interference power received by an IMT-2000 user is less than –109 dBm [2] (the threshold we used), within a range of about 35 km from the transmitter site. This is shown in the last column of Table 1. The range will be limited to 50 km, when transmitting power is 400 kW (a 13 dB increase). In the Los Angeles area, the interference power is far below the threshold because the San Gabriel Mountains alone can cause the 76.9-dB diffraction attenuation (not including free space loss). Thus, interference through terrain diffraction can only play a role within a 50-km range from the transmitter, depending largely on the mountain topography.

3. Interference through Anomalous Modes

While an interference through terrain diffraction is quickly attenuated within a 50-km range, it may suffer only little attenuation and can propagate to a large distance through two anomalous modes as shown in Figure 4 [6,7,8,11]: Mode 1 (which is due to atmospheric effects during clear weather and propagates along the great circle, such as tropospheric scattering and atmospheric ducting) and mode 2 (which can be off the great circle, such as rain scattering or other hydrometeor scattering). As a result, the interference power may greatly exceed the threshold of 3G mobile phone a small percentage of time at a distance that is defined in the previous section by terrain diffraction. Thus, we need to add a correction term for the loss due to terrain shielding effects.

3.1. Attenuation through Mode 1[7,8,11]: As shown in Figure 4, when the atmosphere has strong vertical gradients, propagating waves pointing slightly upward can be trapped within the duct between the ground and a reflected atmospheric layer or within an elevated ducting layer and propagate for a long distance. Tropospheric turbulences and irregularities also can scatter the interference into a large area, which usually define the background noise level. However, after including the terrain shielding effects on the transmitting antenna, the interference power through these modes can be significantly reduced.

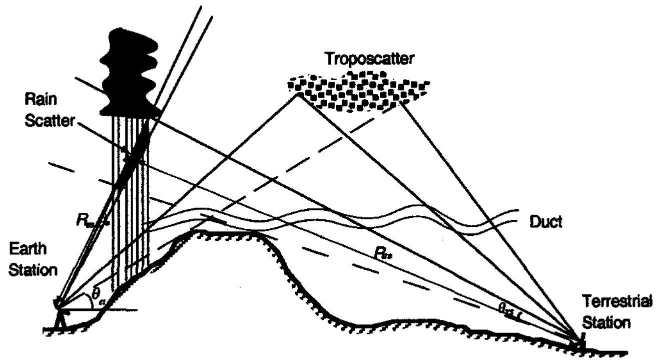

Figure 4. Two interference mechanisms between a DSN transmitter and IMT-2000/UMTS customers beyond line of sight. Rain scattering by a common viewed rain region and atmospheric diffraction can cause trans-horizon interference problems at a very small percentage of time.

For the Goldstone site, the surrounding hilltop has a maximum elevation angle of 4.85° relative to the 70-m transmitting antenna at north and a minimum angle of 1.1° at east. Using the maximum correction (A_h =30 dB), which corresponds to the elevation angle of transmitter (see Figure 2),'et ≤ʲ , the received interference powers for various time percentages are shown in Figure 5. The transmitter antenna side lobe gain G_t = -7 dB and receiving antenna gain $G_r = 0$ dB are used for this calculation. When elevation angles are between 1° and 3°, the loss correction is less than 30 dB (e.g., 'et =1°, A_h =18.8 dB; ᵕet = 2°, A_h = 25.5 dB). The preliminary estimate of coordination distances for various percentages of time with maximum (3° elevation angle) and without terrain shielding (0° elevation) is shown in Table 2. Thus, actual coordination distance should be in a range between the maximum and minimum distances shown in Table 2. For example, for 400-kW transmitting power, the coordination distance is 160 km for 1° elevation shielding and 120 km for 2° at 1.0% of time.

Table 2. Coordination Distances for Mode 1 (Preliminary)

	Without Mountain Shielding		With Mountain Shielding	
	P_t = 20kW	P_t = 400kW	P_t = 20kW	P_t = 400kW
p = 0.1%	235 km	305 km	90 km	160 km
p = 1.0%	185 km	240 km	60 km	110 km
p = 5.0%	138 km	190 km	24 km	72 km

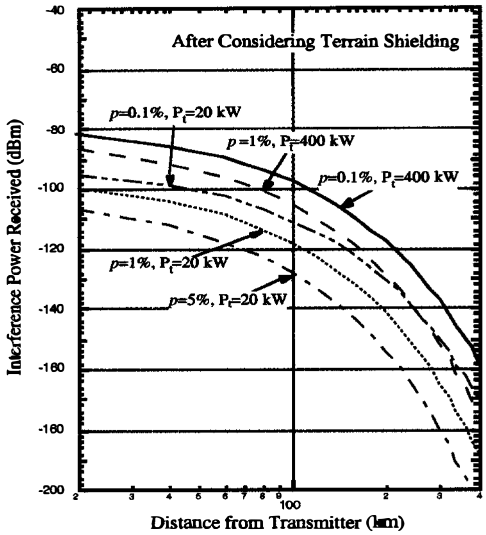

Figure 5. Preliminary estimate of interference power received through mode 1 with mountain shielding effects (additional 30 dB loss).

3.2. Attenuation through Mode 2 [12,13]: We also need to investigate the possibility of interference signals propagating through rain scattering. Even though the rainfall rate is very low in the Goldstone desert area, rain scattering can make it possible for waves to propagate into an area beyond line of sight. Rain droplets can reflect and scatter the waves like a mirror between a transmitter and a trans-horizon receiver. Terrain is expected to have little effect on rain scattering propagation, except for mountain peaks with very large elevations that can block direct illumination from rain clouds.

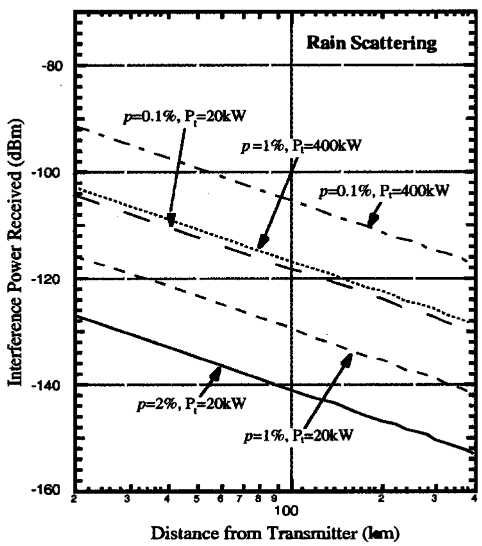

Figure 6. Preliminary estimate of received interference powers through rain scattering modes as a function of distance from DSN Goldstone transmitter for various percentages of time, respectively.

Figure 6 shows interference powers generated through the rain scattering mode as a function of distance for various time percentages p. It indicates that the effect of rain scattering would only exceed the threshold less than 1.0% of the time at distances within 10 km from 20-kW transmitting power and 42 km for 400-kW power. The coordination distances for various percentages of time are shown in Table 3, assuming a –109 dBm threshold. Compared with mode 1, rain scattering appears to be insignificant because of the much smaller coordination distance due to a lower rainfall rate.

Table 3. Coordinate Distances for Mode 2 (Preliminary)

	P_t = 20 kW	P_t = 400 kW
p = 0.1%	35 km	155 km
p = 1.0%	~ 10 km	42 km
p = 2.0%	< 10 km	~10 km

4. Coordination Area for All Propagation Modes

After taking the terrain into account, we have developed a preliminary contour map that includes all propagation modes as shown in Figure 7 for two transmitting power levels under the 1% of time probability. We found that the terrain diffraction propagation has larger attenuation and smaller coordination distance than modes 1 and 2. Depending on surrounding terrain profiles, the interference signals due to diffraction quickly decrease to below the threshold of the 3G mobile systems within a range from 35 km to 50 km. The diffraction effect can be neglected at large distances.

We also found that rain scattering (mode 2) propagation also has a larger loss and smaller coordination distance (10–42 km at 1% of time). This is because of only a very small rain scattering effect on S-band and low rainfall rates at Goldstone.

Because mode 1 has a smaller loss and a longer coordination distance than terrain diffraction and rain scattering, the final coordination distances are basically determined by mode 1. There are some significant differences in the coordination distances with and without terrain shielding around the transmitting antenna. The actual distance is between 110 km (3° elevation shielding) and 170 km (1° elevation shielding) from the Goldstone site for a 400-kW transmitting power under the 1% of the time. For a 20-kW transmitting power, the distance is between 60 km and 110 km. In the north and southeast directions, because of the larger terrain elevation angles around the transmitting antenna, there are shorter coordination distances from the Goldstone site. In the east and northwest directions, the distances are much larger because of lower elevation angles of the surrounding terrain. In the south and southwest sides, the coordination distance contour for 400-kW transmitting power extends to near the San Gabriel mountains, which can block a great deal of the ducting mode transmission from the receiving side in the Los Angeles area.

As shown in Figure 7, both Los Angeles and Las Vegas are just outside of the coordination contour and are free from interference at least 99% of the time. Therefore, we conclude that for a very small percentage of time (1%), atmospheric ducting will be a dominant interference mechanism and will have the largest coordination distance among the three propagation modes.

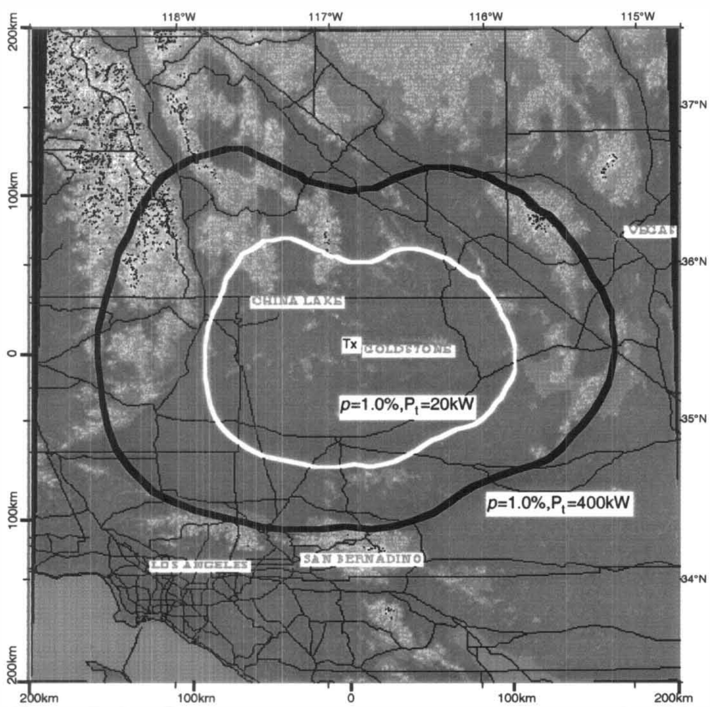

Figure 7. Preliminary coordination contour map for 3G mobile users operating in areas surrounding the DSN Goldstone transmitter: transmitter power = 20-kW (white line) and 400-kW (black line); percent of time =1%; Both Los Angeles and Las Vegas are just outside of the coordination contour and are free from interference at least 99% of time.

Acknowledgements: The research described in this publication was carried out ~~by~~ at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

References

[1] International mobile telecommunications-2000 (IMT-2000), Rec. ITU-R M.687, 1997.
[2] Guidelines for evaluation of radio transmission technologies for IMT-2000, Rec. ITU-R M.1225, 1997.
[3] Spectrum considerations for implementation of international mobile telecommunications-2000 (IMT-2000) in the band 1885-2025 MHz and 2110-2200 MHz, Rec. ITU-R M.1036, 1999.
[4] Christian Ho, Miles Sue, Ted Peng, Peter Kinman and Harry Tan, Interference Effects of Deep Space Network Transmitters on IMT-2000/UMTS Receivers at S-band, *JPL TMO Progress Report*, 42-142, August 15, 2000.
[5] Christian Ho, Miles Sue, Ted Peng, and Ernest Smith, Terrestrial Propagation of 2-GHz Emissions Transmitted from The DSN 70-meter Antenna at Robledo, *JPL TMO Progress Report*, 42-152, February 15. 2003.
[6] Prediction procedure for the evaluation of microwave interference between stations on the surface of the earth at frequencies above about 0.7 GHz, Recommendation ITU-R P.452-9, 1999.
[7] Determination of the coordination area of an earth station operating with a geostationary space station and using the same frequency band as a system in a terrestrial service, Recommendation ITU-R IS.847-1, 1993.
[8] Propagation data required for the evaluation of coordination distances in the frequency range 100 MHz to 105 GHz, Recommendation ITU-R P.620-4, 1999.
[9] Radio Regulations, Appendix S7, (former Appendix 28), Edition 2001, ITU Document, Geneva, 2001.
[10] Propagation by diffraction, Recommendation ITU-R P.526-6, 1999.
[11] Crane, R.K., A review of transhorizon propagation phenomena, *Radio Science*, 16, 649, 1981.
[12] Flock, W.L., Propagation effects on satellite systems at frequencies below 10 GHz, *A Handbook for Satellite Systems Design*, NASA Reference Publication 1102, 1987.
[13] CCIR, Scattering by precipitation, Report 882-1, in Vol. V, *Propagation in Non-ionized Media*, Recommendations and Reports of the CCIR, 1886, Geneva: ITU, 1986.

Biography: Dr. Christian Ho is a senior telecommunications system engineer at Jet Propulsion Laboratory. He is an expert in radio wave propagation in various environments (ionized and non-ionized media). He received his PhD in Space Physics from UCLA and joined JPL in 1993. He has over 100 publications in a wide variety of fields, including radio wave propagation in the Earth's magnetosphere, ionosphere, plasmasphere, solar corona, atmospheric reentry at Venus and Mars; interference propagation in terrestrial environments; Deep Space Network protection; and ITU studies on IMT-2000 and HDFS. He is an expert in ITU (International Telecommunication Union) regulations and spectrum coordination, and he has made many contributions in drafting recommendations and issues for ITU.R Working Groups.

End of File