A Statistical Analysis of the OpenLink Fixed Service (FS) Microwave Database in the 2165 to 2200 MHz Frequency Range

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INTRODUCTION

A Joint Working Group (JWG) has been formed under the auspices of the Telecommunications Industry Association (TIA) comprised of TIA engineering committees TR-34.1 and TR-14.11 and the National Spectrum Manager Association (NSMA). The purpose of the JWG is to conduct a formal study to address the potential for sharing the band 2165-2200 MHz, in the United States, between satellite systems operating in the mobile satellite service (MSS) and microwave systems operating in the fixed service (FS). Although allocations to this band for the mobile satellite services (space-to-Earth) have been adopted by the ITU on a co-primary basis with fixed service services, use of the band in the US by the mobile satellite service providers may not commence before January 1, 2000. One of the key issues in the FCC's 2 GHz Rulemaking is the extent to which the 2165-2200 MHz band can be shared between the MSS and FS providers. The JWG is currently developing a Telecommunications System Bulletin (TSB86) documenting the results of their efforts.

This paper presents statistics for the FS microwave service in the 2165-2200 MHz frequency range. The statistics were derived using the Radio Dynamics Corporation (RDC) OpenLink database and are useful in performing interference analyses between FS and MSS systems. RDC is actively involved in supporting the above JWG and has developed a methodology to quantify the FS link performance in the presence of both multi-path fading and random levels of MSS space-to-Earth transmission interference. This methodology is currently under evaluation for inclusion into TSB86 as the primary means of quantifying the extent to which MSS and FS system can share the 2165-2200 MHz frequency band.

The statistics presented in this paper address modulation type, transmit antenna size, path length, path inclination and azimuth. The percentage of digital and analog links was calculated regarding modulation type. For the other parameters listed above, probability density function (PDF) data and cumulative distribution function (CDF) data was generated.

MODULATION TYPE

Figure 1 displays the distribution of digital and analog microwave links in the 2165-2200 MHz frequency range. As shown, 55% of the links are analog and 45% are analog. The digital links comprise a variety of modulation formats including QPRS9, QPRS25, QPRS49, 4QAM, 8QAM, 32QAM, 64QAM, 256QAM, 8PSK, Duobinary, and VIDVSB. All of the analog links employ FDMFM modulation techniques.

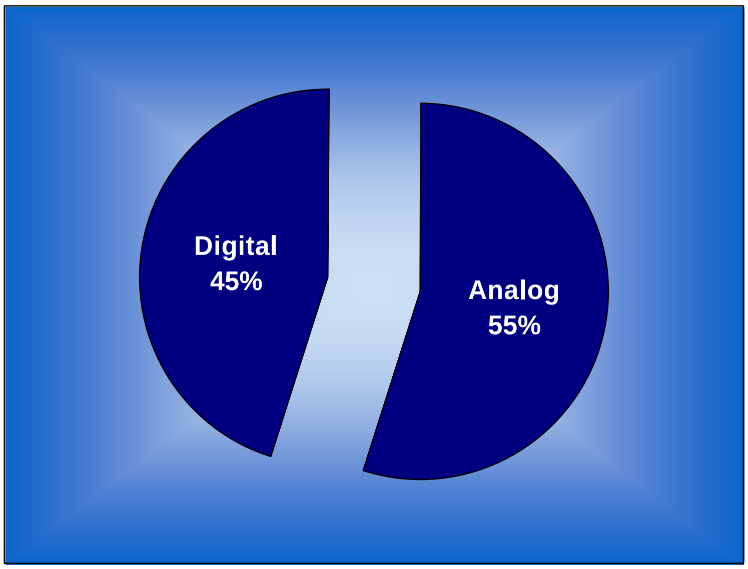

Figure 1: Modulation Type Statistics

TRANSMIT ANTENNA SIZE

Figure 2 displays the PDF and CDF data of the transmit antenna sizes for paths operating in the 2165-2200 MHz frequency range. As shown, over 40% of the paths utilize 6-ft antennas and almost 30% utilize 8-ft antennas. A significant portion of the links have 10-ft and 4-ft antennas – 6% and 12%, respectively. Only 4% of the paths have transmit antennas greater than 10-ft – the maximum size observed is 15-ft for a small number of paths.

The antenna size is a key factor in performing MSS/FS interference analysis. It determines the 3-dB beamwidth of the boresight antenna gain pattern which, in turn, impacts the probability that the MSS interference will be received with maximum gain. It also affects the behavior of the sidelobe gain pattern. This is important since the MSS interference will more likely arrive into the sidelobe of a given FS receive station versus within the 3-dB beamwidth.

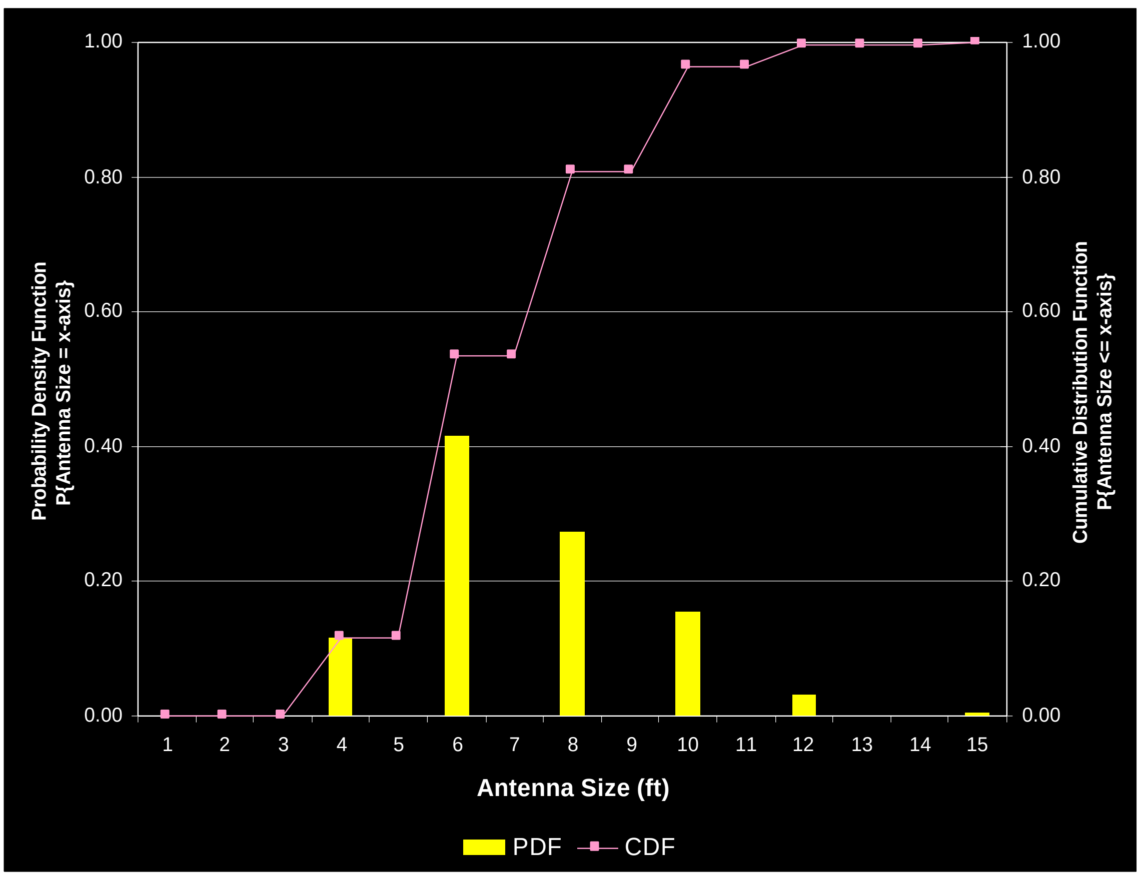

Figure 2: Transmit Antenna Size Statistics

PATH LENGTH

Figure 3 displays the PDF and CDF data of the path length for paths operating in the 2165-2200 MHz frequency range. As shown, most of the path lengths lie in the range 10 to 30 km, with 90% of the path lengths less than or equal to 50 km. The longest path observed was ~260km while the shortest path was on the order of 10s of meters.

The path length is also a factor in performing MSS/FS interference analysis. For longer path lengths, the FS received signal level (RSL) is lower due to a higher propagation loss. All other system parameters being equal, FS links having longer path lengths will likely be less robust in the presence of MSS interference since they will already be operating closer to their performance objective.

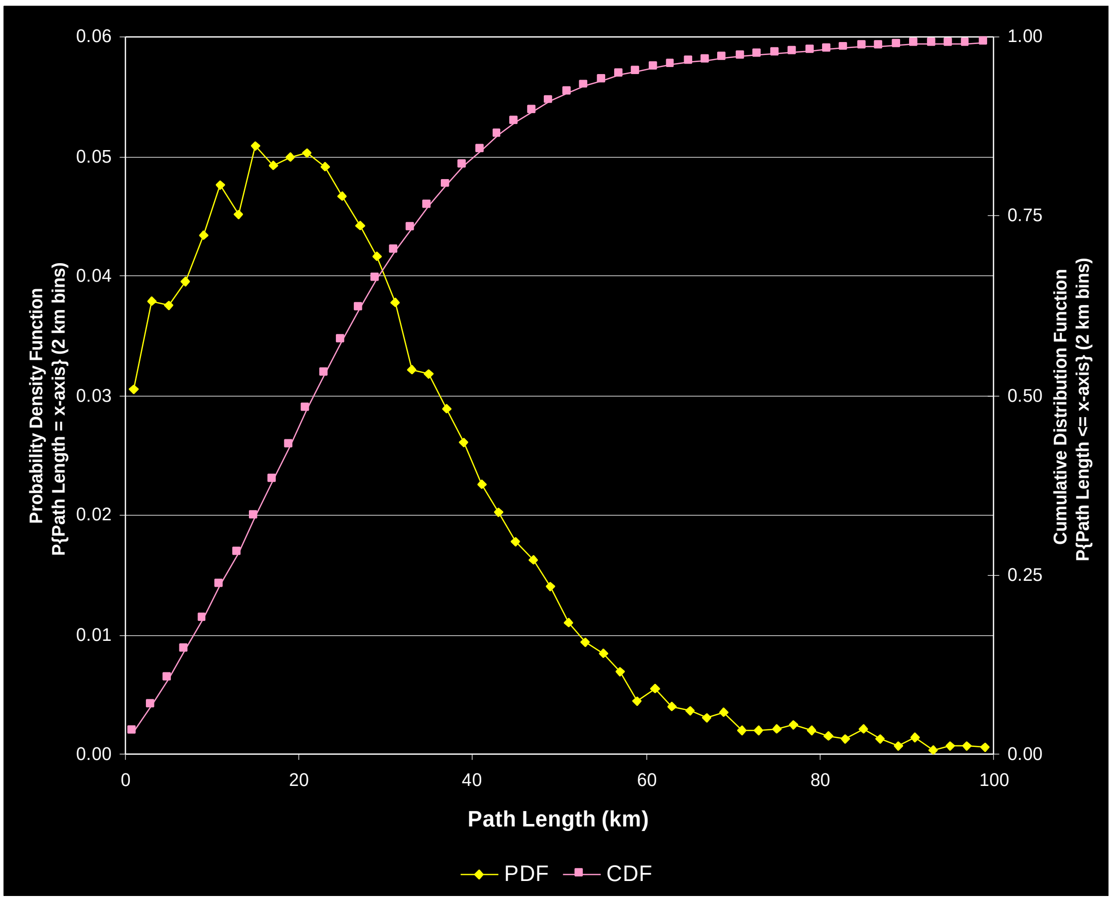

Figure 3: Path Length Statistics

PATH INCLINATION ANGLE

Figure 4 displays the PDF and CDF data of the path inclination angle for paths operating in the 2165-2200 MHz frequency range. The path inclination angle is a function of the difference between transmit and receive antenna heights above sea level and the path length. For the case of equal transmit and receive antenna heights, the inclination angle is 0°. For all other cases, the path inclination angle, θ, can be calculated as follows:

$$\theta = Tan^{-1}\left(\frac{|h_t - h_r|}{d}\right)$$

where:

θ	=	Path Inclination Angle (degrees)
h_t	=	Transmit antenna height above sea level (m)
hr	=	Receive antenna height above sea level (m)
d	=	Path length (m)

For example, a path having transmit and receive antenna heights of 100 meters and 30 meters, respectively, and a path length of 20 km will have a path inclination angle of .2 degrees using the above equation. (Note that the path length, *d,* in the above equation is input in meters versus kilometers.)

As shown in the figure below, FS path inclination angles in the 2165-2200 MHz frequency range are generally quite small, with over 95% of them less than .5 degrees. The higher the path inclination angle, the higher the likelihood that the MSS interference signal will arrive at the FS terminal within the 3-dB beamwidth of the receive antenna. The result is higher gain for the interference signal and, consequently, a higher level of MSS interference power at the receiver. This will increase the deleterious effect that the MSS interference signal will have on the overall FS link performance.

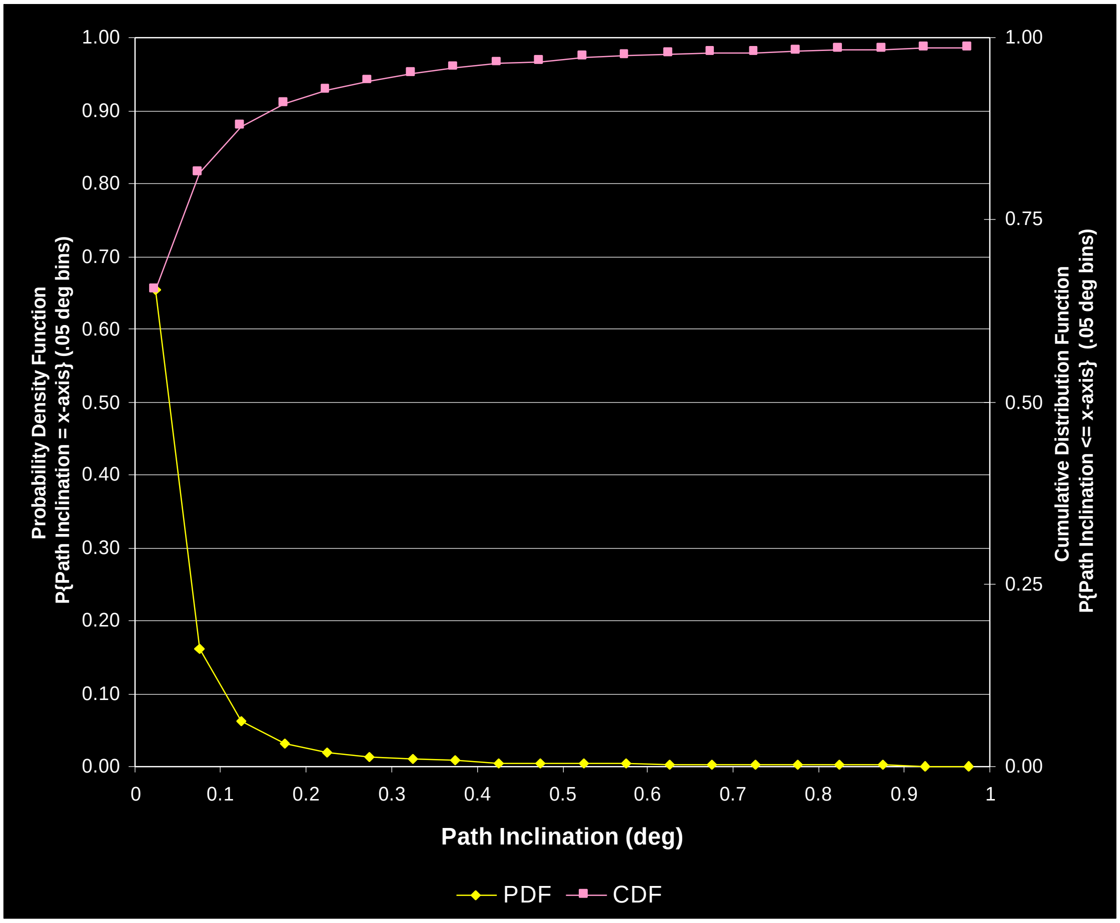

Figure 4: Path Inclination Statistics

PATH AZIMUTH ANGLE

Figure 5 displays the PDF and CDF data of the path azimuth angle for paths operating in the 2165-2200 MHz frequency range. The azimuth angle is the angle measured in a clockwise direction between the direction of the FS path and true North. Thus, if the FS path pointed toward true North, the azimuth angle would be 0 degrees. Similarly, if the FS path pointed directly toward the East, the azimuth angle would be 90 degrees.

As shown below, there is almost a uniform distribution of azimuth angles for the FS microwave paths operating in the 2165-2200 MHz frequency range. A slight increase is observed in the N-S direction (i.e., azimuth angles of 0 degrees and 180 degrees) and E-W direction (e.g., azimuth angles of 90 degrees); however, the difference is negligible for the purposes of this paper.

The effect that the path azimuth angle will have on MSS/FS interference analyses is complex and depends upon the orbital characteristics of the MSS system in question, especially the orbital inclination angle and the satellite altitude. Normally, simulation and/or a parametric analysis are required to determine the limiting azimuth angles. It is good practice to evaluate the impact of MSS interference on FS link performance for a family of azimuth angles.

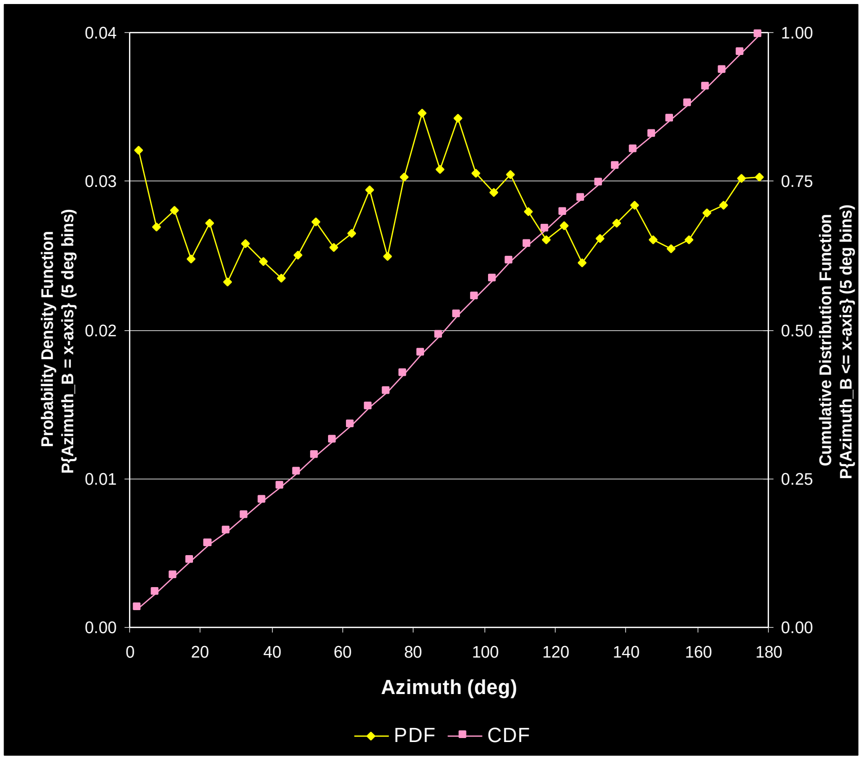

Figure 5: Path Azimuth Angle Statistics

SUMMARY

This paper presented statistics for the FS microwave service in the 2165-2200 MHz frequency range. The statistics were derived using the Radio Dynamics Corporation (RDC) OpenLink database and are useful in performing interference analyses between FS and mobile satellite service (MSS) systems. The statistics generated address modulation type, transmit antenna size, path length, path inclination angle and azimuth angle.

It was shown that approximately 55% of the FS microwave paths are analog and 45% are digital. The most common transmit antenna sizes are 6-ft and 8-ft, with only 4% of the links having antenna sizes greater than 10-ft. Most FS microwave path lengths lie in the 10 to 30 km range, although there are some path lengths as low as several 10s of meters and as long as 260 km. The path inclination angles are small for most paths, with 95% of the paths having inclination angles less than .5 degrees. Finally, it was shown that the distribution of azimuth angles across FS links is nearly flat, with a slight increase in N-S and E-W directions.

Each of these parameters can have a significant impact on MSS/FS interference analysis. Performance evaluations performed by RDC in the past have demonstrated that significant complexity is introduced into the analysis when the effects of several link parameters such as azimuth angle, path length, and path inclination angle are simultaneously combined. Based upon the evaluations performed, it is clear that each path must be evaluated individually and caution must be used before making general comments concerning the relationships between overall link performance and certain link parameters.

As stated previously, RDC is actively involved in supporting the TIA JWG formed to evaluate the potential for MSS/FS sharing in the 2165-2200 MHz frequency band. RDC has developed a methodology to quantify the FS link performance in the presence of both multi-path fading and random levels of MSS space-to-Earth transmission interference. You are invited to view several papers and briefings that RDC has generated on this topic located in the publications section of our homepage at http://www.radyn.com.

RDC and its subsidiaries provide innovative, technically advanced products and services that offer comprehensive solutions for the deployment of Personal Communication Services (PCS), Cellular, Satellite, and Microwave systems. RDC's state of the art products and services have been used by many of the major global telecommunication companies and equipment manufacturers including ICO, Ameritech, AT&T, BellSouth, GTE, Lucent Technologies, MITRE, Omnipoint, Powertel, Southwestern Bell, Sprint, UTAM (Unlicensed Transmission and Management), Union Pacific Railroad and Western Wireless. Our expertise in FS microwave systems and participation in national and international standards organizations, coupled with our technical strength and experience in satellite communications, enable us to provide a unique set of technical services that span the full range of satellite/microwave/PCS interference analysis and coordination activities. For more information concerning this paper or any of the products or services provided by RDC, please contact the author of this paper.