Annex H: Convolutional Approach – Required Parameter Lists

This annex identifies the parameters required to apply the *convolutional approach* analysis method in evaluating MSS downlink interference into FS receive stations.

H.1. Table of Required FS System Parameters

Parameter[1]	Units
Waveform Description	Digital (Plot of power spectral density (PSD) as a function of frequency) Analog (Plot of PSD as a function of frequency and number of channels)
Latitude/Longitude for XMT/RCV antennas	degrees
Height above sea-level for XMT/RCV antennas	meters
Path Length	kilometers
Frequency	GHz
Azimuth of RCV antenna	degrees
FS Receiver Reference Bandwidth	1 MHz
Receive antenna gain pattern[2]	unitless
Noise floor at input of FS receiver[3]	dBW
Total RCV losses (other than propagation)	dB
Theoretical Received Signal Level (RSL) at Input to Receiver[4]	dBm
Receiver Threshold (R_t)	dBm
Terrain Designator	Plains, Hills, or Mountains
Geoclimatic factor, K[5]	unitless
System Length (i.e., route length)	km
Number of Hops	Unitless
Pre-Emphasis?	Yes or No
ATPC?	Yes or No; if Yes, provide type (step or ramp), trigger receive level, nominal, coordinated, and maximum power levels
RCV Antenna Diversity?	Yes or No

H.2. Table of Required MSS System Parameters

Parameter	Units
Waveform Description	Plot of PSD as a function of frequency
GSO, non-GSO, Elliptical, hybrid, etc.	unitless
Number of satellites	unitless
Number of orbital planes	unitless
Number of satellites per orbital plane	unitless
Ascending node separation between planes	unitless
Phase between in-plane satellites[6]	degrees
Apogee of each orbital plane[6]	kilometers
Perigee of each orbital plane[6]	kilometers
Inclination of each orbital plane[6]	degrees
Frequency	GHz
Transmitter antenna gain pattern[7]	unitless
Maximum transmitter power	dBW
Transmitter power model[8]	Unitless
Transmitter RF bandwidth	Hz
Total XMT losses (other than propagation)	dB

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1 Based upon using ITU-R P.530 for the fading model. Slight modifications will be needed if a difference fade model is used.

2 If the FS receive antenna gain pattern is not available, use the default gain patterns provided in the appropriate annex of this Bulletin.

3 If unknown, use a default value of –140 dBW for digital links (corresponds to a noise figure of 4 dB and a bandwidth of 1 MHz) and –164.2 dBW for analog links (corresponds to a noise figure of 4 dB and a bandwidth of 4 kHz).

4 Takes into consideration free space loss.

5 The geoclimatic factor, K, is needed in support of using ITU-R P.530 in order to quantify the probability that the fade on a given link exceeds the link margin. If the geoclimatic factor is not known, use the procedure and default values identified in ITU-R P.530 to estimate it.

6 In most cases, the apogee, perigee and inclination will be constant across orbital planes. Also, the apogee and perigee are equal for circular orbits.

7 If the MSS transmit antenna gain pattern is not available, use the default gain patterns provided in the appropriate annex of this Bulletin.

8 As a minimum, this would include the XMT power level as a function of time for each satellite but could also include information concerning the occupied bandwidth, frequency re-use, transponder loading, etc.

Annex I: Derivation of an Expression for the Margin of an Analog FM-FDM Path Using the Baseband Aggregate Noise Interference Limit

The methodology presented in Section 4 using the *convoluational approach* analysis method begins with the goal of calculating the probability that the received SNR for a given link, SNR_{rcv}, is less than the required SNR, SNR_{rcv}, to meet a particular link availability. The SNRs are measured at RF frequencies. The purpose for this was to facilitate subsequent derivations used to generate Equations 4-4 and 4-10 which represent the probability that the fade experienced on a particular link exceeds the fade margin with and without MSS interference, respectively.

This was convenient for digital microwave paths. However, for analog FM-FDM paths, performance is evaluated in different terms. This is evident when the forms of the analog interference criteria provided in Chapter 3 are considered. It turns out that analyzing the performance for FM-FDM paths naturally leads to the same type of analysis as for the digital paths. The purpose of this Annex is to provide the derivation behind the analysis needed to evaluate the FM-FDM performance criteria. This derivation will lead to basically the same methodology as for the digital cases, as long as the correct interpretation of the various quantities in the analysis is made. These interpretations are provided in this Annex.

The analog FM-FDM performance criteria are in terms of the probability of certain baseband noise limits being exceeded. Consequently, we start with the following expression:

$$P\{p_{rcv,dBm0} > p_{\lim,dBm0}\} \tag{I-1}$$

Where $p_{rcv,dBm0}$ is the baseband received power in in dBm0 and $p_{lim,dBm0}$ is the aggregate noise interference limit for an analog link, also in dBm0, given in section 3.2.1.2. The result of evaluating the above equation is an expression for the probability that the fade experienced on a particular link exceeds a value determined by $p_{lim,dBm0}$. It will be shown that this value can also be expressed in terms of the link margin as was done in Section 4.

Using the results of TSB-10F, Annex A, p_{rcv} can be expressed as follows:

$$p_{rcv,dBm0} = X_{dBm0} - SIR_{rcv,dB} \tag{I-2}$$

where X_{dBm0} is the per-channel load (or average talk power) in dBm0 and $(SIR)_{rcv,dB}$ is the baseband received signal-to-interference ratio in dB. Furthermore, using Equation A-8 of TSB-10F, we can write:

$$SIR_{rcv,dB} = \left(\frac{C}{N+I}\right)_{rcv,dB} + IRF_{dB}(f_c) \tag{I-3}$$

where $IRF_{dB}(f_c)$ is the interference reduction factor, in dB, which depends on the baseband channel frequency and the frequency separation between the carrier frequencies of the desired signal and the interfering signal. The IRF is determined by the characteristics of the FM-FDM receiver and the normalized power spectral densities of the desired signal and the interfering signal. A detailed expression for the *IRF* is given in Annex A of TSB-10F.

Following the same procedure as in Section 4, we can now write:

$$\frac{C}{N \quad I}_{rcv} \quad \frac{P_t G_t G_r \big/ (N \quad I) L_p}{A} \tag{I-4}$$

where the terms in Equation I-4 were previously defined in Section 4 and the above expression is not in dB. Using the definitions for SNR_{link} and I'' from Section 4, we can re-write Equation I-4 as follows:

$$\left(\frac{C}{N+I}\right)_{rcv} = \frac{SNR_{link}}{AI''} \tag{I-5}$$

Expressing the terms of Equation I-5 in dB and using the nomenclature of Section 4, we obtain:

$$\left(\frac{C}{N+I}\right)_{rcv,dB} = SNR_{link,dB} \quad A_{dB} \quad I''_{dB} \equiv SNR_{rcv,dB} \tag{I-6}$$

where we've made use of the definition of $SNR_{rcv,dB}$ from section 4. It we substitute the results of Equations I-2, I-3,and I-6 into Equation I-1 above, we arrive at the following:

$$P\{p_{rcv,dBm0} > p_{\lim,dBm0}\} = P\{A_{dB} > p_{\lim,dBm0} - X_{dBm0} + SNR_{link,dB} - I''_{dB} + IRF_{dB}(f_c)\} \tag{I-7}$$

Note that $p_{lim,dBm0}$, X_{dBm0}, $SNR_{link,dB}$, and $IRF_{dB}(f_c)$ are not random variables. In light of this, it is convenient to define the following two parameters:

$$SNR_{req,dB} \equiv X_{dBm0} - p_{\lim,dBm0} - IRF_{dB}(f_c) \tag{I-8}$$

$$M_{dB} \equiv SNR_{link,dB} - SNR_{req,dB} = SNR_{link,dB} - X_{dBm0} + p_{\lim,dBm0} + IRF_{dB}(f_c) \tag{I-9}$$

Using the results of Equations I-7 and I-9, together with the results of Equation 4-9, we can generate the following relationship:

$$P\{p_{rcv,dBm0} > p_{\lim,dBm0}\} = P\{A_{dB} > M_{dB} - I''_{dB}\} = P\{SNR_{rcv,dB} < SNR_{req,dB}\} \quad \text{(I-10)}$$

Note that A_{dB} and I''_{dB} in Equation I-10 above are essentially the same variables as were used in Section 4.2.1. Comparing Equation I-10 above with Equation 4-9 of Section 4.2.1.3, we see that the *convolutional approach* analysis method is applicable to both analog FM-FDM paths and digital paths if we interpret the parameter M_{dB} as shown in Equation I-9.

The aggregate noise interference limit, $p_{lim,dBm0}$, can be converted to units of pWp0 as follows:

$$\begin{aligned} p_{\lim,dBm0p} &= 87.5 + p_{\lim,dBm0} \\ p_{\lim,pW0p} &= 10^{\frac{p_{\lim,dBm0p}}{10}} \end{aligned} \quad \text{(I-11)}$$

Using the results above, we obtain the final relationship between link margin and the baseband aggregate noise power limit, provided in units of pW0p, for an analog FM-FDM link:

$$M_{dB} = SNR_{link,dB} - X_{dBm0} + 10Log_{10}(p_{\lim,pW0p}) - 87.5 + IRF_{dB}(f_c) \quad \text{(I-12)}$$

Annex J: Derivation of an Expression for the C/(N+I) Limit in terms of the Baseband Aggregate Noise Interference Limit for Analog FM-FDM Paths

The methodology presented in Section 4 using the Monte Carlo approach will result in data generated that describes the exceedence function of the ratio of received RF carrier-to-noise plus interference power, in dB, at the FS receiver. We will express this ratio as follows:

$$\left(\frac{C}{N+I}\right)_{rcv,dB} \tag{J-1}$$

The analog FM-FDM performance criteria provided in Section 3.2.1.2 are given in terms of the probability of certain baseband aggregate noise interference limits being exceeded. These limits, referred to in this annex by the term $p_{lim,pW0p}$, are given in units of pW0p.

The purpose of this Annex is to derive an expression that defines a limit for the ratio of received RF carrier-to-noise plus interference power, in dB, at the FS receiver in terms of the baseband aggregate noise interference limits provided in Section 3.2.1.2 for an analog FM-FDM link.

Using the results of TSB-10F, Annex A, the baseband aggregate noise interference limit given in units of dBm0, $p_{lim,dBm0}$, can be expressed as follows:

$$p_{\lim,dBm0} = X_{dBm0} - SIR_{\lim,dB} \tag{J-2}$$

where X_{dBm0} is the per-channel load (or average talk power) in dBm0 and $(SIR)_{lim,dB}$ is the baseband received signal-to-interference ratio limit, in dB, corresponding to $p_{lim,dBm0}$. Furthermore, using Equation A-8 of TSB-10F, we can write:

$$SIR_{\lim,dB} = \left(\frac{C}{N+I}\right)_{\lim,dB} + IRF_{dB}(f_c) \tag{J-3}$$

where $IRF_{dB}(f_c)$ is the interference reduction factor, in dB, and depends on the baseband channel frequency and the frequency separation between the carrier frequencies of the desired signal and the interfering signal. The IRF is determined by the characteristics of the FM-FDM receiver and the normalized power spectral densities of the desired signal and the interfering signal. A detailed expression for the *IRF* is given in Annex A of TSB-10F.

Substituting the results of Equation J-3 into Equation J-2 and solving for $[C/(N+I)]_{lim,dB}$ results in:

$$\left(\frac{C}{N+I}\right)_{\lim,dB} = X_{dBm0} \quad IRF_{dB}(f_c) \quad p_{\lim,dBm0} \tag{J-4}$$

The aggregate noise interference limit, $p_{lim,dBm0}$, can be converted to units of pWp0 as follows:

$$p_{\lim,dBm0} = 10Log(p_{\lim,pWop}) - 87.5 \tag{J-5}$$

Using the results above, we obtain the final expression that defines a limit for the ratio of received RF carrier-to-noise plus interference power, in dB, at the FS receiver in terms of the baseband aggregate noise interference limits provided in Section 3.2.1.2 for an analog FM-FDM link:

$$\left(\frac{C}{N+I}\right)_{\lim,dB} = X_{dBm0} \quad IRF_{dB}(f_c) + 87.5 \quad 10Log(p_{\lim,pWop}) \tag{J-6}$$

Annex K: Multiple-Beam Satellite Antennas and Frequency Re-Use

Figure K-1 shows an example of a multiple beam satellite antenna employing 163 spot beams with a four-cell frequency re-use pattern. Typically, individual spot beams are pre-assigned specific frequency blocks.

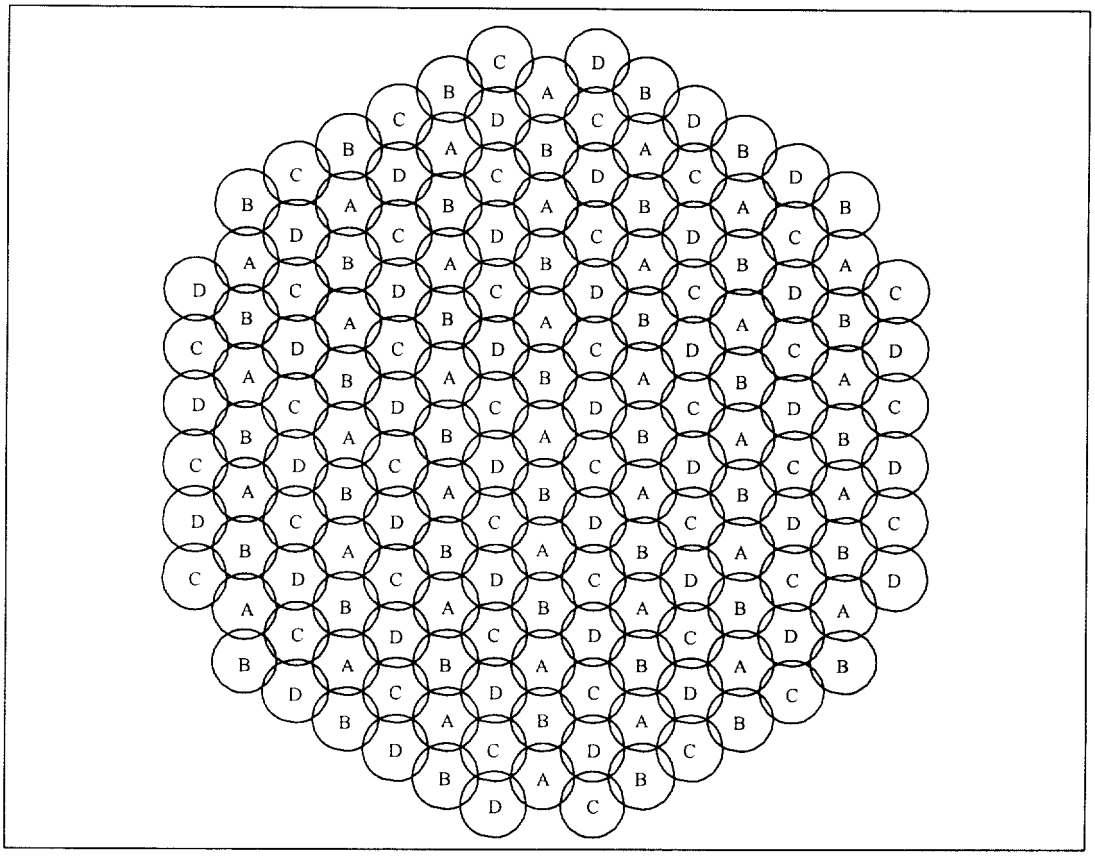

Figure K-1. Example of Multiple Spot Beams Using a Four-Cell Frequency Re-use Pattern

Spectrum Partitioning

Some MSS networks may partition the available spectrum into frequency blocks. These blocks are pre-assigned to specific beam types (e.g., A, B, C, etc.). For example, consider the case of an MSS system which divides its available spectrum into eight frequency blocks of 1 MHz each. Assuming a system with a four-cell frequency re-use pattern, each beam type is pre-assigned two specific frequency blocks. The two frequency blocks are separated in frequency by the total number of blocks divided by two, or in this example, 4 MHz.

BEAM TYPE	ASSIGNED FREQUENCY BLOCK
A	F1 or F5
B	F2 or F6
C	F3 or F7
D	F4 or F8

Traffic Assignment

MSS channels (and frequencies) are assigned dynamically as MSS users access the system. The Network Management Center (NMC) assigns individual frequencies to the users in such a way as to minimize intra-system, adjacent and co-channel interference. Whenever possible, the NMC distributes the frequencies uniformly across the available spectrum, subject to system design characteristics and operational constraints (inherent or intentional). Generally, within the bounds of these constraints, the MSS user traffic will be assigned uniformly between all beams and all frequencies over time.

Impact on Interference Analysis

The MSS frequency re-use capabilities and frequency assignment methodologies are relevant factors in the determination of interference to or from a fixed system. In the example above, the distribution of frequency blocks among the various spot beams reduces the interference into any FS receiver, especially those with a bandwidth of 4 MHz or less as compared to the unrealistic case where all beams are assumed to transmit simultaneously on the same frequency.

Annex L: Industry Contributions

Document Register

Committee: TR-34.2/TR14.11/NSMA JWG Year: 1996 - 1998

Doc No	Title	Source
TR-34.2/96/001	Frequency Sharing between MSS and FS, a Fixed Service Perspective	AT&T
TR-34.2/96/002	Characteristics of FS equipment	Alcatel
TR-34.2/96/003	Comments on TSB 10F	COMSAT
TR-34.2/96/004	ICO-P service link parameters	COMSAT
TR-34.2/96/005	Overview of proposed methodology for evaluation of potential interference	Sullivan Telecom Associates
TR-34.2/96/006	Consideration of multiple MSS networks for computation of the aggregate interference to fixed service receivers	Sullivan Telecom Associates
TR-34.2/96/007	MSS/FS Sharing algorithms document	COMSAT
TR-34.2/96/008	MSS networks for which filings have been submitted to the ITU Radio-Communications Bureau	COMSAT
TR-34.2/96/009	A simple, preliminary examination of proposed Mobile Satellite Service frequency sharing with the 2 GHz Fixed Service	Edwards & Kelcey Wireless Alcatel
TR-34.2/96/010	Potential propagation models for characterizing desired Signals in TR-34/TR-14 analysis	Sullivan Telecom Associates
TR-34.2/96/011	Draft Annotated Outline	Sullivan Telecom Associates
TR-34.2/96/012	ICO Orbital Parameters	COMSAT
TR-34.2/96/013	Railroad Applications of FS Microwave Communications	Union Pacific Railroad
TR-34.2/96/014	Power Utility Applications of FS Microwave Communications	PEPCO/UTC
TR-34.2/96/015	Pipeline Applications of FS Microwave Communications	API
TR-34.2/96/016	Interference from Mobile Satellite Systems through Terrain Scattering	Joseph Shapira
TR-34.2/96/017	Visualyse, Visual Interference Analysis Software	Transfinite Systems
TR-34.2/96/018	Modeling of MSS Interference	Radio Dynamics

TR-34.2/96/019	Further Results: MSS Interference Example (4/25/97)	Radio Dynamics
TR-34.2/96/020	Multiple MSS Systems and the Reference Bandwidth in the Culling Process	ICO
TR-34.2/96/021	A Comparison of TIA Bulletin 10F and ITU-R Rec.P.530 Multipath Fading Models	AT&T
TR-34.2/96/022	Further Results on MSS/FS Interference (6/5/97)	Radio Dynamics
TR-34.2/96/023	Preface	Motorola
TR-34.2/96/024	Section 2.2.x, Multiple Beam Satellite Antennas & Frequency Reuse	ICO
TR-34.2/96/025	Section 2.3, Fixed Service Interference Criteria	AT&T/Alcatel
TR-34.2/96/026	Section 3.1.2, Nature of Interfering Signals from Mobile-satellite Service Networks	AT&T
TR-34.2/96/027	Section 4, Examples of Estimating Interference Between Fixed-Service systems and Mobile-satellite Systems	Iridium
TR-34.2/96/028	Annex D, Section 2	ICO
TR-34.2/96/028a	Three "Legs" to the Evaluation	Radio Dynamics
TR-34.2/96/029	A Methodology for Calculating the Impact of MSS Space-to Earth Interference on FS radio-Relay Ground Stations	Radio Dynamics
TR-34.2/96/030	Supporting Analysis for a Proposed Methodology to Quantify MSS/FS Interference	Radio Dynamics
TR-34.2/96/031	Section 2.2, Mobile Satellite Service System Characterization	Radio Dynamics
TR-34.2/96/032	Description of Methodology for the Development of Criteria for sharing between non-GSO MSS Systems and the Fixed Service in the 1 - 3 GHz Frequency Band	Stanford Telecom
TR-34.2/96/033	Section 3.6, MSS/FS Interference Evaluation Methodology (will become section 3.5, the current section 3.5 becomes 3.6)	Radio Dynamics
TR-34.2/96/034	Annex I, Methodology to be used in Transforming PDF Data for the r.v Idbw ito PDF Data for the r.v.I''db (Annex G)	Radio Dynamics
TR-34.2/96/035	Horizons system Level Information	Inmarsat
TR-34.2/96/036	MSS\FS Frequency Coordination Process	Ad hoc Committee on Procedures

TR-34.2/96/037	A Methodology for Calculating the Impact of MSS to FS Interference with FS Automatic Transmit Power Control	Radio Dynamics
TR-34.2/96/038	Section 2.7, MSS\FS Interference Criteria	Radio Dynamics
TR-34.2/96/039	Modification of Recommendation ITU-R M.1319	Inmarsat
TR-34.2/96/040	Mobile Satellite Service System Characteristics (Section 2.3)	Radio Dynamics
TR-34.2/96/041	Required FS Parameters, Required MSS Parameters	Radio Dynamics
TR-34.2/96/042	Multiple Exposure Allowance	Inmarsat
TR-34.2/96/043	Derivation of an Expression for the Margin of an Analog FM-FDM Path using the Baseband Aggregate Noise Interference Limit (Annex I)	Radio Dynamics
TR-34.2/96/044	Calculation Method for MSS-Only Interference into Analog FS Receivers	Inmarsat
TR-34.2/96/045	Analysis Methods and their Application. Proposed First Sub-Section of Section 4	Sullivan Telecom Associates ICO Global
TR-34.2/96/046	Comments on TSB-86 Draft Version 07.1	ICO Global
TR-34.2/96/047	Applying the TSB86 Evaluation Methodology Using the "Convolutional Approach. Includes Required System Parameters and Performance Results for Examples 1 and 2.	Radio Dynamics
TR-34.2/96/048	Generic Method. Proposed replacement for section 2 of Annex D – Traffic Models.	
TR-34.2/96/049	Is the MSS-Only Analysis "Conservative" Relative to the Convolutional or Monte-Carlo Approaches?	Radio Dynamics
TR-34.2/96/050	Multiple Exposure Allowance – Inmarsat proposal	Inmarsat
TR-34.2/96/051	Multiple Exposure Allowance – RDC proposal	Radio Dynamics
TR-34.2/96/052	Notes on the Multiple Exposure Allowance	STA/ICO
TR-34.2/96/053	Impact of Fixed Service Transmissions into MSS Earth Stations (Section 5)	Iridium
TR-34.2/96/054	Section 7 Interference Mitigation Techniques	Lucent
TR-34.2/96/055	Draft Element of TSB 86 Version 7.4 Modifying Sections 1.2 and 4.1	ICO
TR-34.2/96/056	Fig. 4-1 Sequence of Analysis Methods to Assess MSS Interference into FS Assignments in the 2160 – 2200 MHz Band	ICO
TR-34.2/96/057	Annex A: Multipath Fading Model	W Rummler

TR-34.2/96/058	A Statistical Examination of Digital FSA Path Performance, at Actual Link Margins, with a and without MSS Interference	ICO
TR-34.2/96/059	Figures 4-1a & 4-1b, Methodology roadmap	Radio Dynamics
TR-34.2/96/060	Long Term Limit for "MSS Only" Interference to Analog Links	ICO
TR-34.2/96/061	Performance Degradation Limit (PDL)	ICO
TR-34.2/96/062	Addressing IM Noise Issue for the aggregate Noise Case	ICO

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