Analysis of the Interference Potential to Amateur Radio from RFID Signals Proposed in ET Docket 01-278

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Analysis of Savi Technology's September 30, 2002 Ex Parte Submission

On September 30, 2002, Savi Technology submitted in this proceeding a written Ex Parte analysis of the "potential for interaction" (i.e. interference potential) between "Amateur portable units" and radio frequency identification systems (RFID) that would operate under the rules proposed in this proceeding. It was allegedly submitted "pursuant to an FCC staff inquiry to Savi as to the likely effects, if any, of emissions from RFID tag readers on Amateur operations." The Savi submission suffers many of the same fatal defects as its prior submissions; it is extremely misleading in both its premises and its conclusions; and it limits its analysis to Amateur station configurations and emissions not applicable to the frequency band at issue. This same problem has occurred repeatedly in this proceeding, drawing Savi's *bona fides* into serious question.

The presentation contains several technical errors. Among these, the signal level conditions, choice of operating mode and the test methods assumed by Savi are not appropriate to determine the interference potential to Amateur Radio from RFID devices operating in accordance with the proposed rules. Savi has made a number of repetitive presentations to the Commission on this same subject, and each contains errors and misrepresentations intended to obscure the fact that near-continuous signals of 110,000 microvolts/meter at 3 meters peak will disrupt Amateur radio communications for miles and would inevitably cause harmful interference to allocated services.

Technical Error

Although Savi is now (unlike their previous submissions) using the correct formula to determine field strength versus distance from a radiating source, its calculation of the average power of pulsed transmissions employed is in error. Savi correctly calculates the peak field and peak power EIRP of the radiator that created that field, but their conclusion (that the average power of a FM transmitter with a pulsed 10% duty cycle is 20 dB less than the peak envelope power) is incorrect.

The error may have resulted from Savi's misinterpretation of the Commission's rules. Section 15.231(b) permits a field strength of 11,000 microvolts/meter at 3 meters from the radiating source for compliant periodic radiators. However, Sec. 15.35 permits averaging of the field values. This allows as much as 20 dB more transmitter power for very short pulsed transmissions at the duty cycles permitted for periodic radiators. The rules reflect a recognition that a low-duty, short period transmission (< 0.1 seconds) offers less interference potential than do near-continuous transmissions, which are being proposed in this proceeding.

Section 15.35 permits the average of the electric field strength voltage to be determined over a 0.1 second time period. For a 10% on/off duty factor, this does result in a permitted 20 dB increase in the peak level of the radiated emissions (20log10 of the ratios of the average of the field). However, the average *power* over a pulse train for a transmitter that is operating 10% of the time is determined by average of the *square* of the fields (Power = E^2/R). A transmitter that is transmitting for 10% of the time is using 10% of the power (-10 dB), not 1% (-20 dB) of the power over the averaging period. This could be verified by taking a root mean square of the voltages in one pulse train and using that to calculate the power using the well-known power formula, $P = E^2/R$.

Unreasonable Assumptions

In reaching its conclusion that the proposed regulations will not result in harmful interference to the Amateur Radio Service, Savi has used distance assumptions that are *not* representative of the conditions under which RFID devices might be deployed. Savi's assumptions about the expected desired signal levels of receivers in common use in the Amateur Radio Service are not even close to what is encountered in routine station operation in the subject band, 425-435 MHz.

Distances

Savi has indicated that the expected distance between deployed RFID devices and stations (fixed or portable, apparently) in the Amateur Radio Service would be 1 km. This distance is not reasonable. While this may apply to some large warehouses or ports, in many areas of the country it is not at all uncommon for light industrial areas or storage facilities to be located immediately adjacent to residences. The proposed rules do not limit the deployment of RFID devices to areas located more than 1 km from the nearest residence. Nor could such a limitation, if imposed, be enforced, due to the unlicensed character of RFID devices.

Line-Of-Sight Levels

Savi's analysis of interference from its RFID devices to Amateur FM transceivers is, as will be discussed, almost entirely irrelevant to the frequency band at issue, since FM repeater communications are not conducted at 425-435 MHz. However, assuming *arguendo* that the analysis might be relevant to some portion of the overall assessment of interference potential, or assuming that the Commission might be considering some other frequency segment for Savi's devices, Savi's assumptions are, once again, fatally flawed.

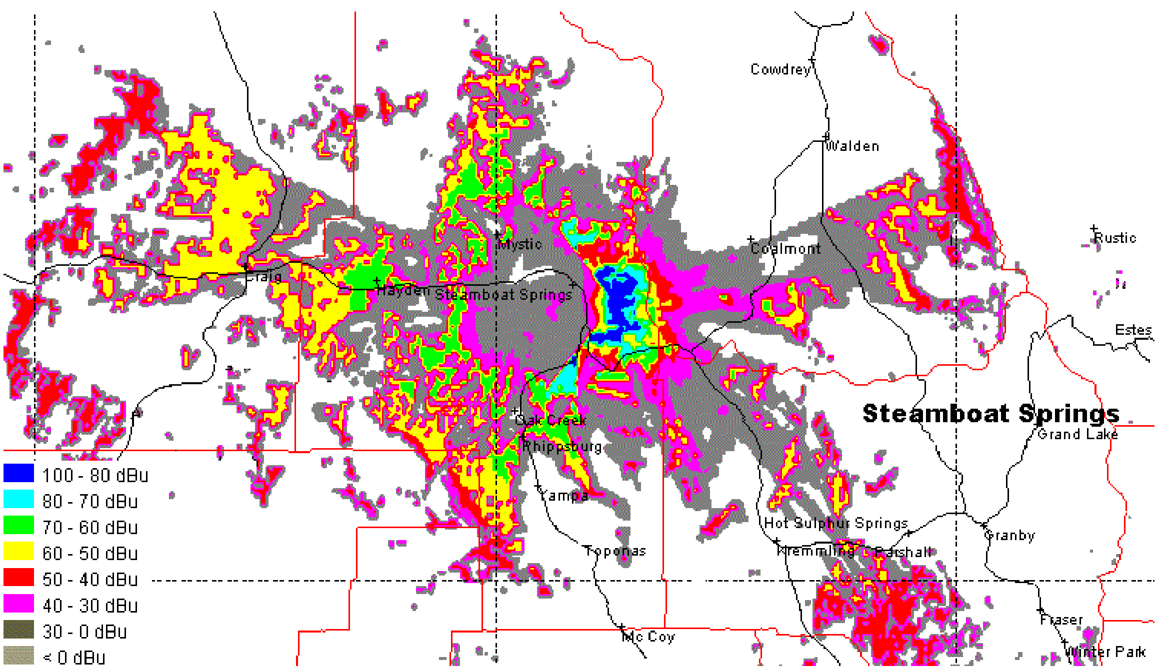
Savi alleges that an Amateur Radio repeater, at normal antenna heights, would result in coverage distances corresponding to Line-of-Sight (LOS) desired-signal levels of –89 dBW to –99.4 dBW. These levels are well over an S9 signal level, with S9 being designated as being "extremely strong" in the standard, accepted definition of the term. S9 represents a received signal level of 50 microvolts across 50 ohms, or –103 dBW[1]. In tests in the ARRL's Laboratory, ARRL staff measured 47 dB of FM quieting on a Yaesu Model FT-897, 420-450 MHz FM transceiver when the receiver was receiving a signal level of –119 dBW, a full 30 dB below the level that Savi used

[1] The International Amateur Radio Union Region 1 S-meter standard is available from: http://www.algonet.se/~k-jarl/ssa/IARU/smeter.html.

for its calculation. Most amateur sources consider 20-dB quieting to be "full quieting", indicating that the levels Savi assumes are tens of dB over the minimum levels that would be expected in practice. The receiver tested has a 12 dB SINAD sensitivity of –153 dBW.

Therefore, the level Savi assumes as a "minimum" (LOS) expected, desired signal level is typical of what would be found ***close*** to a transmitter. An RSL of –89 dBW would be obtained approximately only 10 km LOS between a 25-watt 430 MHz repeater and a mobile receiver using a modest 0 dBi gain whip antenna. In fact, Amateur repeater communications are conducted at far, far longer path lengths. The signal level, chosen (apparently arbitrarily) by Savi to support its claim that its devices will not cause harmful interference, is *not* representative of the minimum reasonable levels for amateur communication, or even of typical levels surrounding an amateur repeater. It is an arbitrarily high signal level, which Savi either knew or should have known is improper and misleading.

The following map shows the range of a 70-cm band amateur repeater located near Steamboat Springs, CO. Although repeaters are generally not used in th part of the band at issue in this proceeding, Savi has continually focused on FM and repeater operation. Thus, this 70-cm band repeater range is included as an example in response to Savi's argument regarding the line-of-sight range of amateur stations. The range of SSB and CW Amateur stations routinely exceed 200 km. On this map, the range of this repeater is greater than 200 km in some directions, not the 10 km that Savi's erroneous data suggests. While this represents a repeater with a large range typical in western States, repeaters even in urban environments with antennas installed at a lower height operate at ranges in excess of 50 km typically. Naturally, over most of a repeater's range, signal levels are much lower than the arbitrarily high level of –89 dBW chosen by Savi.



Antenna Gains

In the overly simplified information Savi has presented in its September 30, 2002 Ex Parte submission, it is evident from the calculations that a 0 dBi gain antenna was presumed for the Amateur station. This is a reasonable figure for a hand-held FM transceiver, but at 420-450 MHz, Amateur stations use antennas that range from 5-dBi omnidirectional gain for FM stations to tens of dB of directional gain for weak-signal and television stations. Savi's use of 0 dBi for its calculations contributed to the errors Savi is makes in its assumptions and its erroneous conclusion that near-continuous RFID operation will not cause harmful interference to the Amateur Radio Service.

Reference Circuits

In comments and Ex Parte submissions in this proceeding, ARRL has provided reference circuits showing the typical configuration and technical specifications of Amateur stations within the 425-435 MHz band. That information is restated herein, as are calculations of the levels of RFID signals relative to the typical levels in the Amateur Radio reference circuits. Rather than showing that the relative signal level (RSL) of the RFID signal will result in a C/(N+I) ratio of 20 to 30 dB, as Savi calculates from its inappropriate assumptions, these realistic assumptions establish that the C/(N+I) could be negative tens of dB. In its previous presentations, ARRL provided the Commission with such calculations for most of the operating modes in common use in the Amateur Radio Service. In some cases, the C/(N+I) ratio was worse than –60 dB.

FM Operating Mode and 12 dB SINAD

In a number of its presentations, including the September 30, 2002 filing, Savi repeatedly claimed that, because the FM operating mode offers some degree of limiting of noise and a capture effect, RFID signals will not cause harmful interference to Amateur operation. FM Limiting does indeed offer some suppression of noise, but only if the desired signal is significantly stronger than the noise level. ARRL has previously presented the Commission with a detailed set of measurements showing the degradation of the 12 dB SINAD level of an FM receiver against various levels of simulated RFID signals. The conclusions previously submitted by ARRL are valid: the 12 dB SINAD of the receiver tested was, predictably, substantially degraded by the presence of the simulated RFID signal.

Diversity of Amateur Operation

The foregoing notwithstanding, any conclusions reached about the degradation of FM Amateur operation are of limited relevance, and represent an interference "best case" from Savi's perspective. In the frequency range under consideration in this proceeding, the Amateur Radio Service typically uses emission modes other than FM, and virtually no repeaters are found in this segment. FM represents just one of many operating modes that amateurs employ. Most Amateur operation in the 425-435 MHz band includes various weak-signal modes such as SSB. The non-FM modes are used for terrestrial, satellite or Earth-moon-Earth (EME) communications, or amateur television, to name just a few. In its previous presentations, ARRL provided detailed calculations and field tests demonstrating significant, harmful interference from signals at the levels and duty cycles proposed in the rules.

Savi's Lack of Specific Test Conditions

The calculations and test results that ARRL has provided to the FCC included sufficient detail about test conditions, signal levels and equipment in each case, to allow a complete engineering analysis. ARRL included information about the equipment being used, its calibration, its measured power levels, antenna gains, feed-line losses, duty factors and frequencies of the test signals. This is necessary to determine the accuracy and applicability of the test method and results.

Savi has not presented even minimally necessary levels of detail in its tests and reports, and as the result, no such conclusions can be drawn. In this recent Ex Parte presentation, Savi summarizes its testing as follows:

> "Tests with handheld FM receivers at distances of less than 10 meters have shown that the RFID interrogator signals will not break the FM receiver squelch. These tests have also verified that when receiving desired signals, the FSK RFID signal is not detected."

These "results" are directly contrary to the 12-dB SINAD degradation measurements on FM receivers that ARRL has made. They are completely contrary to the field tests that ARRL has done, and as well to an analysis of the expected desired signal and noise levels from the RFID systems proposed in this proceeding. There simply is not enough detail in Savi's report to determine what level of desired signal was being received or the frequency of the desired signal compared to the RFID signal. Just to point out a few potential problems with this inadequate test methodology, Savi did not state whether the RFID signal being tested was one of the present models that meet the present requirements of Section 15.231, or if it was a radiated simulation of the RFID system being proposed. No indication was made of the squelch sensitivity or the antenna gain on the amateur FM handheld receiver, to name just two critical technical omissions. The Commission cannot rely on Savi's tests. It must use standard test methods and objective methodology. ARRL's laboratory and field tests have demonstrated that the near-continuous RFID signals being proposed will cause harmful interference to the Amateur Radio Service. The inquiry should end there.

Calculations Versus Reference Circuits

ARRL's 420-450 MHz reference circuits for Amateur stations show that Amateurs often are communicating with RSLs ranging from –196 dBW for weak-signal EME communication to –139 dBW for modest FM receiving systems. In an earlier submission, ARRL outlined the expected increase in ambient noise levels from simulated RFID systems as proposed at distances of 10 through 1000 meters. In all cases, the increase in noise level was tens of dB.

The following table summarizes some of the information from earlier ARRL filings and presentations:

Operating mode	***Desired RSL dBW***[2]	***Average power RFID RSL at 30 meters dBW***[3]	***Average power RFID RSL at 100 meters dBW***	***Average power RFID RSL at 1000 meters dBW***
CW EME (typical)	-195 dBW MDS	-102 dBW	-112 dBW	-132 dBW
SSB base (typical)	-165 dBW MDS	-93 dBW	-103 dBW	-123 dBW
FM base station (typical)	-145 dBW for 12 dB SINAD	-98 dBW	-108 dBW	-128 dBW
FM repeater (typical)	-145 dBW for 12 dB SINAD	-98 dBW	-108 dBW	-128 dBW
Analog TV (typical)[4]	-138 dBW for minimal signal	-82 dBW	-92 dBW	-112 dBW

Conclusions:

Savi Technology's latest Ex Parte presentation offers nothing new, but again provides a flawed technical analysis of largely irrelevant interference characteristics, with insufficient technical detail to satisfy normal scientific methods. Apparently, the only way that Savi can claim that no harmful interference to the Amateur Radio Service from RFID devices using signal levels and duty cycles that would be permitted under the proposed rules is to underestimate the average transmit signal level by 10 dB; underestimate the gain of the Amateur receiving antenna by at least 5 dB; overestimate the likely separation between an RFID device and nearby amateur installations by at least a factor of 10 (a 20 dB change in free-space path loss); and overestimate the LOS desired signal of an Amateur repeater by tens of dB. In short, Savi has failed utterly to make its case. In its presentations, ARRL has demonstrated that the proposed signals would result in significant interference levels to nearby amateur communications. These signal levels and transmit duty cycles are not at all appropriate for the 425-435 MHz band. RFID systems can be designed, built and operated under other provisions of the Commission's Rules, and in other bands. **The Commission's proposal in this case is not justifiable and must be terminated without action.**

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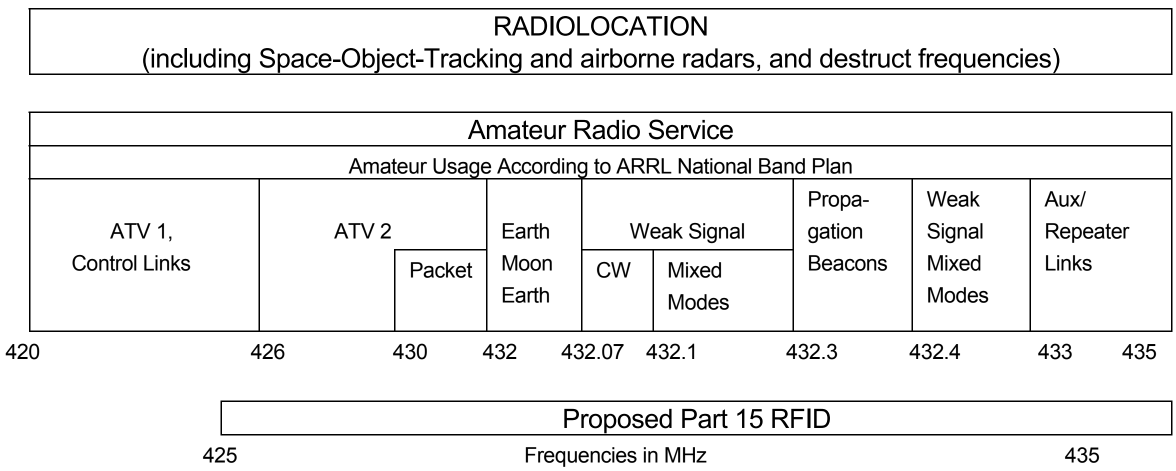
[2] The desired RSLs are based on typical ambient noise levels, receiver sensitivity and receive system antenna gains and feed-line and other losses.

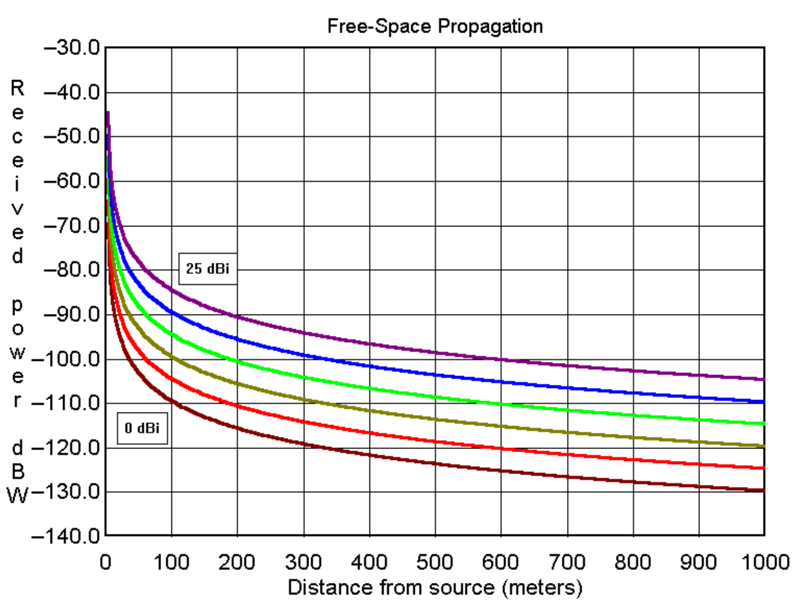
[3] The RSLs are based on 11,000 microvolts/m at 3 m, distance path loss and receive system antenna gain and feed-line and other losses. They have also been corrected for bandwidth.

[4] An analog TV channel is 6 MHz wide. This is greater than the bandwidth of the proposed RFID signal, so no correction for bandwidth has been applied.

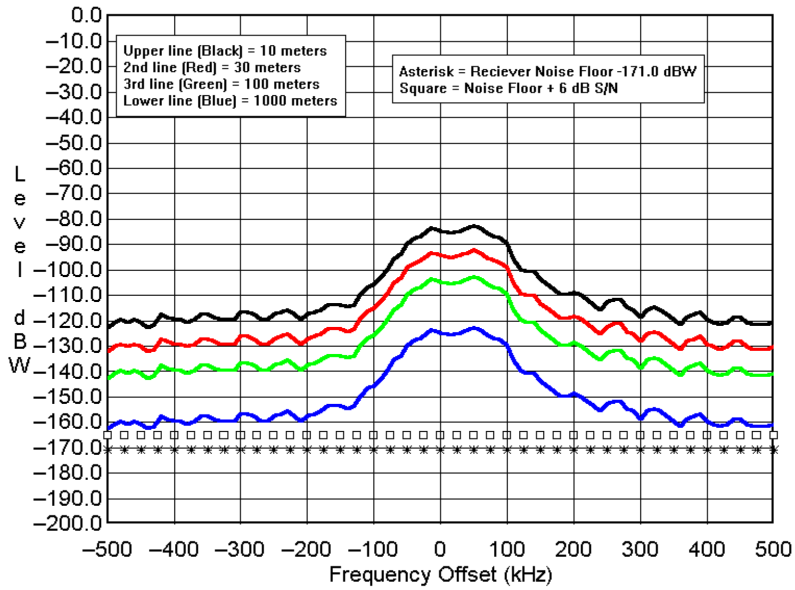
Appendix A: Summaries and Selected Sections of ARRL's Previous Ex Parte Filings

January 14, 2002 ARRL Ex Parte Presentation: ARRL demonstrated to the FCC that the rules change proposed to put high-level Part emissions on portions of the 70-cm amateur band usually used for various "weak-signal" applications. ARRL also provided to the FCC calculations that demonstrate that the signals that would be permitted under the rules change could be at a very high level if the RFID transmitters were located relatively close to Amateur Radio installations.



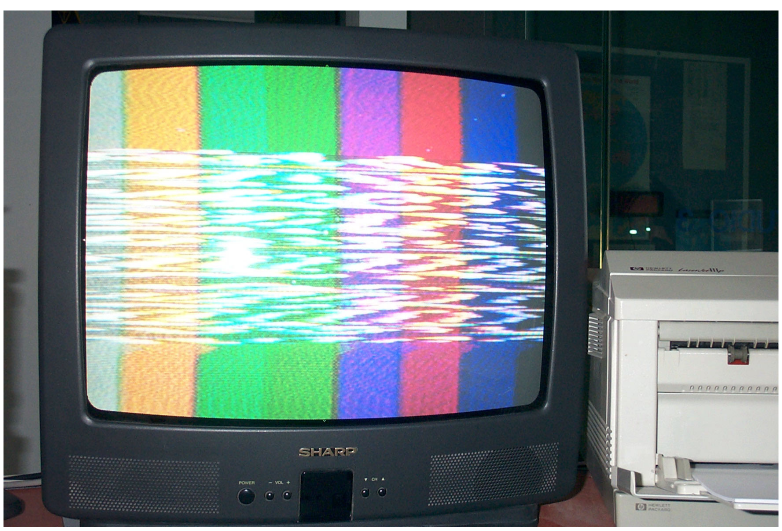


This shows the calculated RSLs from a source that is radiating 11,000 microvolts/meter. The proposed rules change would permit signal levels of 110,000 microvolts/meter peak, a peak power 20 dB higher than that which is permitted without the averaging permitted under Sec. 15.35. This is a conservative estimate. The curves show the RSLs vs different receive antenna gains.



This is the calculated average-power RSL from a typical RFID transmitter at various distances from a typical 70-cm SSB receiver. Even at 1 km line-of-site separation, the interfering signal is over 30 dB higher than the minimum receive-system capability. Such a system would seriously degrade the range of the amateur station, whose antenna is typically situated to obtain maximum line-of-site propagation. The weak signals that amateurs often employ are represented by the squares at the bottom of the graph.

April 23, 2002 ARRL Ex Parte Presentation: ARRL provided the Commission with the results of measurements it had made at amateur station W1AW, studying the effects of simulated RFID signals similar to what is being proposed by the rules change. These simulations were operated at test signals under Part 97. The results obtained were within a few dB of what had been calculated, using methods outlined in ARRL's earlier Ex Parte presentations.



Under the proposed rules, amateurs that experience interference from a single RFID device could see this level of interference continuing for 120-second periods, with 10-second breaks between transmissions. The source was located 100 meters distance from this 70-centimeter band analog television receiver.

Appendix B: Complete reference circuits for the Amateur Radio Service use of the 420-450 MHz band

High End 70 cm SSB Amateur Station:

The typical SSB amateur station communicates with other SSB/CW stations using troposcatter or any other propagation mode available. These high power levels are not used for Earth-to-space use in the amateur satellite service.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	Random	
Information Rate	Speech	
Emission Type(s)	2K50J3E	
Transmitter Power (dBW)	30	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	Horizontal	
Antenna Maximum Gain (dBi)	22.8	
Maximum e.i.r.p. (dBW)	51.8	
Receiver IF Bandwidth	SSB:2500 Hz	
Receiver Noise Figure (dB)	0.5	
Receiver System Noise (dBW)	-171.8(155 Kelvin background)	
Receiver Signal-to-Noise Ratio (dB)	+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

Typical 70 cm SSB Amateur Station

The typical SSB amateur station communicates with other SSB/CW stations using troposcatter or any other propagation mode available. These high power levels are not used for Earth-to-space use in the amateur satellite service.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	Random	
Information Rate	Speech	
Emission Type(s)	2K50J3E	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 2	Receive: 0
Antenna Polarization	Horizontal	
Antenna Maximum Gain (dBi)	18	
Maximum e.i.r.p. (dBW)	36	
Receiver IF Bandwidth	SSB:2500 Hz CW:100Hz	
Receiver Noise Figure (dB)	1	
Receiver System Noise (dBW)	-171(155 Kelvin background)	
Receiver Signal-to-Noise Ratio (dB)	+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

High-End 70 cm CW Amateur Station

The High-End CW amateur station communicates with other stations using troposcatter or any other propagation mode available. These high power levels are not used for Earth-to-space use in the amateur satellite service.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	Random	
Information Rate	10 bit/s	
Emission Type(s)	100HA1A	
Transmitter Power (dBW)	31.7	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	Horizontal	
Antenna Maximum Gain (dBi)	22.8	
Maximum e.i.r.p. (dBW)	53.5	
Receiver IF Bandwidth	CW:100Hz	
Receiver Noise Figure (dB)	.5	
Receiver System Noise (dBW)	-185.8 (1555 Kelvin background)	
Receiver Signal-to-Noise Ratio (dB)	+1	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propgation mode	

Typical 70 cm CW Amateur Station

The typical CW amateur station communicates with other stations using troposcatter.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	Random	
Information Rate	10 bit/s	
Emission Type(s)	100HA1A	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 2	Receive: 2
Antenna Polarization	Horizontal	
Antenna Maximum Gain (dBi)	18	
Maximum e.i.r.p. (dBW)	36	
Receiver IF Bandwidth	CW:100Hz	
Receiver Noise Figure (dB)	1	
Receiver System Noise (dBW)	-185.874	
Receiver Signal-to-Noise Ratio (dB)	+1	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on the propagation mode	

High End 70 cm FM mobile Amateur Station

The typical FM-mobile amateur station can communicate with other FM voice amateur stations.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	5-kHz steps	
Information Rate	Speech	
Emission Type(s)	15K0F3E or 15K0G3E	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 1	Receive: 1
Antenna Polarization	Vertical	
Antenna Maximum Gain (dBi)	1	
Maximum e.i.r.p. (dBW)	20	
Receiver IF Bandwidth	15kHz	
Receiver Noise Figure (dB)	2	
Receiver System Noise (dBW)	-160.3	
Receiver Signal-to-Noise Ratio (dB)	+7 (for 12 dB SINAD)	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

Typical 70 cm FM mobile Amateur Station

The typical FM mobile amateur station can communicate with other FM voice amateur stations and repeaters using line of sight and diffraction propagation modes.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	5-kHz steps	
Information Rate	Speech	
Emission Type(s)	15K0F3E or 15K0G3E	
Transmitter Power (dBW)	14	
Transmission Line Loss (dB)	Transmit: 1	Receive: 1
Antenna Polarization	Vertical	
Antenna Maximum Gain (dBi)	1	
Maximum e.i.r.p. (dBW)	14	
Receiver IF Bandwidth	15kHz	
Receiver Noise Figure (dB)	2	
Receiver System Noise (dBW)	-160.3	
Receiver Signal-to-Noise Ratio (dB)	+7 (for 12 dB SINAD)	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

High End 70cm FM-voice fixed Amateur Station

This station can communicate with other FM voice amateur stations using line of sight and diffraction propagation modes.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	5 kHz steps	
Information Rate	Speech	
Emission Type(s)	15K0F3E or 15K0G3E	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 3	Receive: 3
Antenna Polarization	Vertical	
Antenna Maximum Gain (dBi)	20.8	
Maximum e.i.r.p. (dBW)	39.8	
Receiver IF Bandwidth	15kHz	
Receiver Noise Figure (dB)	2	
Receiver System Noise (dBW)	-163	
Receiver Signal-to-Noise Ratio (dB)	+7 (for 12 dB SINAD)	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

Typical 70cm FM-voice fixed Amateur Station

The typical FM voice station can communicate with other FM voice amateur stations using line of sight and diffraction propagation modes.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	5 kHz steps	
Information Rate	Speech	
Emission Type(s)	15K0F3E or 15K0G3E	
Transmitter Power (dBW)	14	
Transmission Line Loss (dB)	Transmit: 3	Receive: 3
Antenna Polarization	Vertical	
Antenna Maximum Gain (dBi)	5	
Maximum e.i.r.p. (dBW)	16	
Receiver IF Bandwidth	15kHz	
Receiver Noise Figure (dB)	2	
Receiver System Noise (dBW)	-157	
Receiver Signal-to-Noise Ratio (dB)	+7 (for 12 dB SINAD)	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

High End 70 cm Voice Repeater Amateur Station

The high end FM repeater station extends the range of mobile stations

Characteristics	Values	
Frequency Band (MHz)	420-431, 433-435, 438-450 MHz	
Channel Spacing	25 kHz	
Information Rate	Speech	
Emission Type(s)	15K0F3E or 15K0G3E	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 3	Receive: 3
Antenna Polarization	Vertical	
Antenna Maximum Gain (dBi)	5 (300m height above average terrain)	
Maximum e.i.r.p. (dBW)	22	
Receiver IF Bandwidth	15kHz	
Receiver Noise Figure (dB)	2	
Receiver System Noise (dBW)	-157.9	
Receiver Signal-to-Noise Ratio (dB)	+7 (for 12 dB SINAD)	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

Typical 70 cm Voice Repeater Amateur Station

The typical FM repeater station extends the range of mobile stations

Characteristics	Values	
Frequency Band (MHz)	420-431, 433-435, 438-450 MHz	
Channel Spacing	25 kHz	
Information Rate	Speech	
Emission Type(s)	15K0F3E or 15K0G3E	
Transmitter Power (dBW)	15	
Transmission Line Loss (dB)	Transmit: 3	Receive: 3
Antenna Polarization	Vertical	
Antenna Maximum Gain (dBi)	5 (300m height above average terrain)	
Maximum e.i.r.p. (dBW)	17	
Receiver IF Bandwidth	15kHz	
Receiver Noise Figure (dB)	2	
Receiver System Noise (dBW)	-157.9	
Receiver Signal-to-Noise Ratio (dB)	+7 (for 12 dB SINAD)	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	Depends on propagation mode	

High End 70 cm Packet Amateur Station

Packet stations are typically used for point to point links on this band.

Characteristics	Values
Frequency Band (MHz)	430-431MHz, 440.95-441.1 MHz
Channel Spacing	25kHz, 100 kHz
Information Rate	1.2, 4.8,9.6, 56 kbit/s
Emission Type(s)	15K0F3D, 15K0G3D, 15K0G3D, 70K0G3D
Transmitter Power (dBW)	20
Transmission Line Loss (dB)	Transmit: 2 Receive: 2
Antenna Polarization	Vertical
Antenna Maximum Gain (dBi)	18
Maximum e.i.r.p. (dBW)	36
Receiver IF Bandwidth	15 kHz, 15 kHz, 15 kHz, 70 kHz
Receiver Noise Figure (dB)	1 dB
Receiver System Noise (dBW)	-163, -163, -156
Receiver Signal-to-Noise Ratio (dB)	+7 for 12 dB SINAD
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined
Maximum Path Length (km)	Depends on propagation mode

Typical 70 cm Packet Amateur Station

The typical packet station can communicate with other packet stations using line-of-sight and diffraction propagation modes.

Characteristics	Values
Frequency Band (MHz)	430-431MHz, 440.95-441.1 MHz
Channel Spacing	25kHz, 100 kHz
Information Rate	1.2, 4.8,9.6, 56 kbit/s
Emission Type(s)	15K0F3D, 15K0G3D, 15K0G3D, 70K0G3D
Transmitter Power (dBW)	14
Transmission Line Loss (dB)	Transmit: 2 Receive: 2
Antenna Polarization	Vertical
Antenna Maximum Gain (dBi)	2
Maximum e.i.r.p. (dBW)	14
Receiver IF Bandwidth	15 kHz, 15 kHz, 15 kHz, 70 kHz
Receiver Noise Figure (dB)	1 dB
Receiver System Noise (dBW)	-163, -163, -156
Receiver Signal-to-Noise Ratio (dB)	+7 for 12 dB SINAD
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined
Maximum Path Length (km)	Depends on propagation mode

High-End Beacon Amateur Station

Beacons are one-way transmissions for the purpose of providing amateurs real-time indications of band openings, i.e., that a viable propagation path exists between the beacon station and the receiving station. In addition, they may be used for gathering statistics for improvement of propagation prediction programs.

Characteristics	Values
Frequency Band (MHz)	432.0-432.4
Channel Spacing	Random
Information Rate	Slow Morse, typically
Emission Type(s)	100HA1A, 100HJ2A
Transmitter Power (dBW)	15 (KH6HME)
Transmission Line Loss (dB)	1
Antenna Polarization	H
Antenna Maximum Gain (dBi)	20.8
Maximum e.i.r.p. (dBW)	34.8
Receiver IF Bandwidth	100 Hz
Receiver Noise Figure (dB)	1
Receiver Thermal Noise (dBW)	-185
Receiver Signal-to-Noise Ratio (dB)	+1
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined
Availability Target %	99
Maximum Path Length (km)	Depends on the propagation mode

Typical Beacon Amateur Station

Beacons are one-way transmissions for the purpose of providing amateurs real-time indications of band openings, i.e., that a viable propagation path exists between the beacon station and the receiving station. In addition, they may be used for gathering statistics for improvement of propagation prediction programs.

Characteristics	Values
Frequency Band (MHz)	432.0-432.4
Channel Spacing	Random
Information Rate	Slow Morse, typically
Emission Type(s)	100HA1A, 100HJ2A
Transmitter Power (dBW)	10
Transmission Line Loss (dB)	1
Antenna Polarization	H
Antenna Maximum Gain (dBi)	3
Maximum e.i.r.p. (dBW)	12
Receiver IF Bandwidth	100 Hz
Receiver Noise Figure (dB)	1
Receiver Thermal Noise (dBW)	-185
Receiver Signal-to-Noise Ratio (dB)	+1
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined
Availability Target %	99
Maximum Path Length (km)	Depends on the propagation mode

High-End SSB Amateur Earth Station

The High-end SSB amateur earth station can communicate with other SSB stations via amateur-satellite linear transponders. The table below shows parameters for the earth station transmitting to and receiving from the satellite, not the satellite itself. In reality, a given satellite would be transmitting or receiving in the 435-438 MHz band, not both at the same time.

Characteristics	Values	
Frequency Band (MHz)	435-438	
Channel Spacing	Random	
Information Rate	Speech	
Emission Type(s)	2H50J3E	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	Linear	
Antenna Maximum Gain (dBi)	20	
Maximum e.i.r.p. (dBW)	39	
Receiver IF Bandwidth	2.5 kHz	
Receiver Noise Figure (dB)	1	
Receiver Thermal Noise (dBW)	-174	
Receiver Signal-to-Noise Ratio (dB)	+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Availability Target %	99	
Maximum Path Length (km)	Distance to satellite	

Typical SSB Amateur Earth Station

The typical SSB amateur earth station can communicate with other SSB stations via amateur-satellite linear transponders. The table below shows parameters for the earth station transmitting to and receiving from the satellite, not the satellite itself. In reality, a given satellite would be transmitting or receiving in the 435-438 MHz band, not both at the same time.

Characteristics	Values	
Frequency Band (MHz)	435-438	
Channel Spacing	Random	
Information Rate	Speech	
Emission Type(s)	2H50J3E	
Transmitter Power (dBW)	15	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	RHCP	
Antenna Maximum Gain (dBi)	12	
Maximum e.i.r.p. (dBW)	26	
Receiver IF Bandwidth	2.5 kHz	
Receiver Noise Figure (dB)	1	
Receiver Thermal Noise (dBW)	-174	
Receiver Signal-to-Noise Ratio (dB)	+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Availability Target %	99	
Maximum Path Length (km)	Distance to satellite	

High-End CW Amateur Earth Station

The high-end CW amateur earth station can communicate with other CW stations via amateur-satellite linear transponders. The table below shows parameters for the earth station transmitting to and receiving from the satellite, not the satellite itself.

Characteristics	Values	
Frequency Band (MHz)	435-438	
Channel Spacing	Random	
Information Rate	Morse code	
Emission Type(s)	100HA1A	
Transmitter Power (dBW)	20	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	Linear	
Antenna Maximum Gain (dBi)	20	
Maximum e.i.r.p. (dBW)	39	
Receiver IF Bandwidth	100 Hz	
Receiver Noise Figure (dB)	1	
Receiver Thermal Noise (dBW)	-189 (cold sky, 20 K background)	
Receiver Signal-to-Noise Ratio (dB)	+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Availability Target %	99	
Maximum Path Length (km)	Distance to satellite	

Typical CW Amateur Earth Station

The typical CW amateur earth station can communicate with other CW stations via amateur-satellite linear transponders. The table below shows parameters for the earth station transmitting to and receiving from the satellite, not the satellite itself.

Characteristics	Values	
Frequency Band (MHz)	435-438	
Channel Spacing	Random	
Information Rate	Morse code	
Emission Type(s)	100HA1A	
Transmitter Power (dBW)	15	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	RHCP	
Antenna Maximum Gain (dBic)	12	
Maximum e.i.r.p. (dBW)	26	
Receiver IF Bandwidth	100 Hz	
Receiver Noise Figure (dB)	1	
Receiver Thermal Noise (dBW)	-188 (cold sky, 50 K background)	
Receiver Signal-to-Noise Ratio (dB)	+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Availability Target %	99	
Maximum Path Length (km)	Distance to satellite	

High End ATV Amateur Station

The high end ATV station uses a tube type amplifier to take advantage of band openings that are the result of tropspheric ducting.

Characteristics	Values
Frequency Band (MHz)	420-450 MHz
Channel Spacing	6 MHz
Information Rate	
Emission Type(s)	Visual 5M25C3F Aural 36K0F3E
Transmitter Power (dBW)	30.0 (K8AEH)
Transmission Line Loss (dB)	2
Antenna Polarization	H
Antenna Maximum Gain (dBi)	17.9
Maximum e.i.r.p. (dBW)	45.9
Receiver IF Bandwidth	4.2 MHz
Receiver Noise Figure (dB)	1(Mast mounted preamp)
Receiver Thermal Noise (dBW)	-138.8
Receiver Signal-to-Noise Ratio (dB)	35 dB (4 dB for marginal contacts)
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined
Availability Target %	99
Maximum Path Length (km)	Depends on the propagation mode

Typical ATV Amateur Station

The typical ATV amateur station communicates with other ATV stations and repeaters using LOS modes. Longer communications are possible with good tropospheric ducting conditions.

Characteristics	Values
Frequency Band (MHz)	420-450 MHz
Channel Spacing	6 MHz
Information Rate	
Emission Type(s)	Visual 5M25C3F Aural 36K0F3E
Transmitter Power (dBW)	20.0
Transmission Line Loss (dB)	2
Antenna Polarization	H
Antenna Maximum Gain (dBi)	17.9
Maximum e.i.r.p. (dBW)	35.9
Receiver IF Bandwidth	4.2 MHz
Receiver Noise Figure (dB)	1(Mast mounted preamp)
Receiver Thermal Noise (dBW)	-138.8
Receiver Signal-to-Noise Ratio (dB)	35 dB
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined
Availability Target %	99
Maximum Path Length (km)	Depends on the propagation mode

High End 70 cm EME Amateur Station

The high-end EME model is based on N2IQU and NC1I who use different antenna types.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	Random	
Information Rate	CW:10bit/s	
Emission Type(s)	50H0A1A	
Transmitter Power (dBW)	31.7	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	Rotatable Linear	
Antenna Maximum Gain (dBi)	34 N2IQU 48' dish; 32 NC1I yagis	
Maximum e.i.r.p. (dBW)	64.7; 62.7	
Receiver IF Bandwidth	SSB:2500 Hz CW:50 Hz	
Receiver Noise Figure (dB)	0.28	
Receiver System Noise (dBW)	CW:-195.6 SSB:-178.6	
Receiver Signal-to-Noise Ratio (dB)	CW:1 SSB:+6	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Maximum Path Length (km)	396,000 one way to moon at nominal apogee	

Large dish or yagi array and 1500 watts.

Typical 70 cm EME Amateur Station

The typical EME model is capable of CW communication with other EME stations.

Characteristics	Values	
Frequency Band (MHz)	420-450	
Channel Spacing	Random	
Information Rate	CW: 10 bit/s	
Emission Type(s)	50H0A1A	
Transmitter Power (dBW)	30	
Transmission Line Loss (dB)	Transmit: 1	Receive: 0
Antenna Polarization	Predominately H, also rotatable linear	
Antenna Maximum Gain (dBi)	26	
Maximum e.i.r.p. (dBW)	55	
Receiver IF Bandwidth	CW: 50 Hz	
Receiver Noise Figure (dB)	0.3	
Receiver System Noise (dBW)	-195.5	
Receiver Signal-to-Noise Ratio (dB)	+1	
Maximum Long-Term Interference Power [dB(W/Hz)]	To be determined	
Availability Target %	99 (when moon is in view)	
Maximum Path Length (km)	396,000 one way to moon at nominal apogee	

Typical antennas are 8 large yagis or 4 smaller yagis and 1 kW.