|  |  |
| --- | --- |
| **Radiocommunication Study Groups** |  |
|  |  |
|  |  |
| Source: Document 5A/TEMP/68 | **Annex 11 to Document 5A/198-E** |
| **20 November 2012** |
| **English only** |
| Annex 11 to Working Party 5A Chairman’s Report | |
| Working document towardS a preliminary draft new Report ITU-R М.[5 MHZ COMPAT] | |
| Compatibility analysis of possible amateur systems with fixed, land mobile, radiolocation and maritime mobile services in the frequency band 5 250-5 450 kHz | |

# 1 Introduction

The high frequency (HF) band is the highest frequency band that supports propagation of radio signals via a reflected path incident on the ionosphere. This is called ionospheric or sky-wave propagation. Because of this unique characteristic, an important feature of the HF spectrum is its ability to support long range communications via sky-wave propagation. However, one disadvantage of long range propagation is the likelihood that noise and interference from distant sources may affect a desired communication. Therefore, the usability of HF sky-wave communication channels depends on both signal propagation and the absence of excess noise and interference. While propagation conditions have been studied extensively over several decades, there are relatively few published studies that have looked at noise and interference in the HF band.

This Report examines interference caused by stations of the amateur service to operation of the systems of fixed, radiolocation, land mobile and maritime mobile services and gives conclusions relating to compatibility feasibility of these services.

# 2 Specific operation of the frequency band 5 250-5 450 MHz

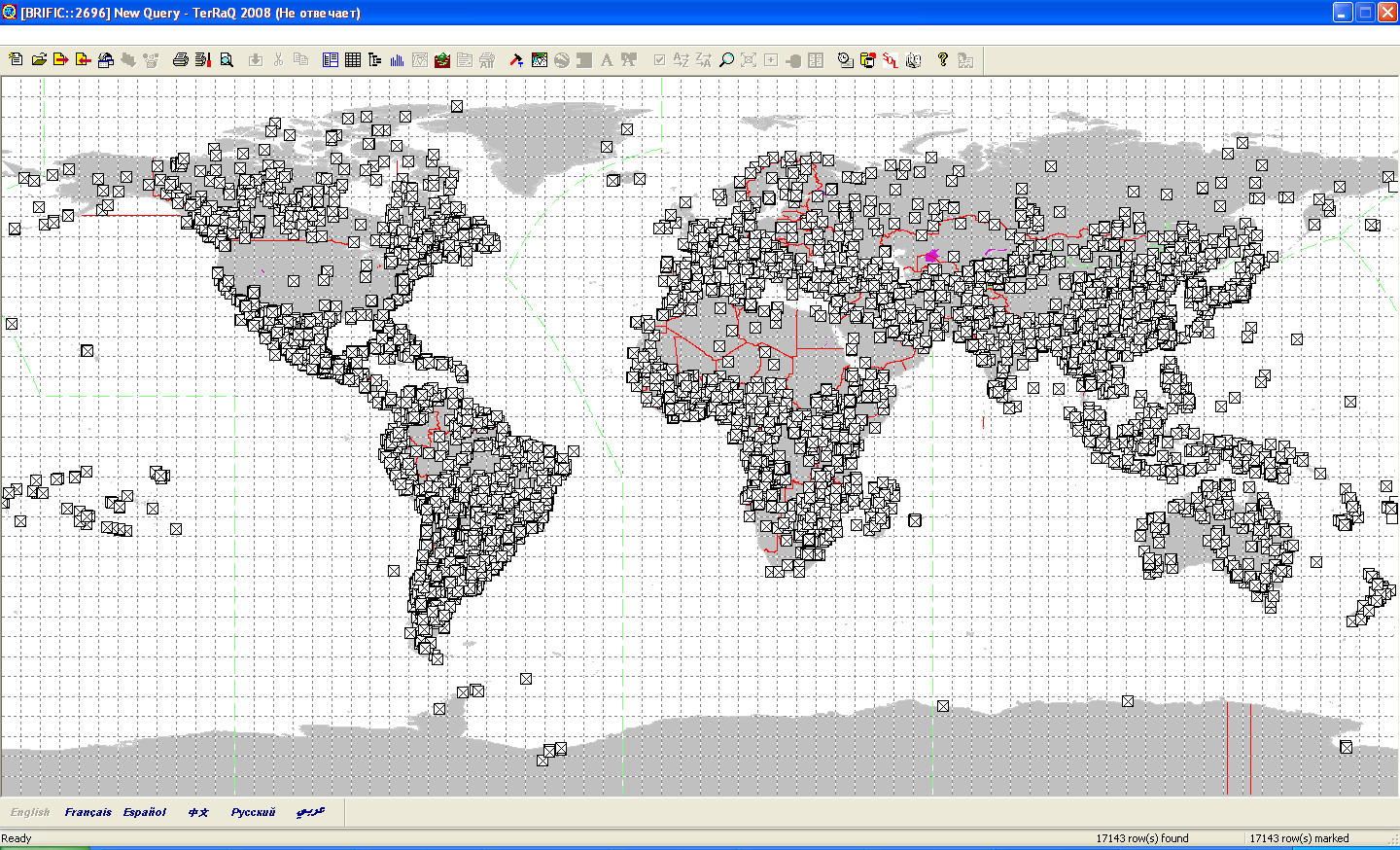
In accordance with Frequency Allocation Table of Radio Regulations the frequency band 5 250‑5 450 kHz is allocated to fixed and mobile (except aeronautical mobile) services on global primary basis.

The analysis of International Frequency Master Register showed that currently 17 143 frequency assignments are notified in this frequency band. The location of these frequency assignments, as produced by the TerRaQ program, is shown in Figure 1. [The TerRaQ program is updated periodically by the BR.] The notified frequency assignments operate mainly in the fixed, land mobile and maritime mobile services. They provide voice and data transmission in telephone and telegraphy modes and can be used for different services including providing [safety of navigation] and communication in sparsely populated areas and in difficult to access areas.

In Russia this frequency band is heavily used by systems of high, medium and low output power. It is due to territory size where communication shall be provided (in Russia radio path length can be several thousand km). In addition in the territory of the Russian Federation there are large sparsely populated areas, difficult to access and remote areas and also areas of Far North where it is not reasonable to develop traditional mobile network and also satellite communication systems.

FigURE 1

Location of stations operating in the frequency band 5 250-5 450 kHz

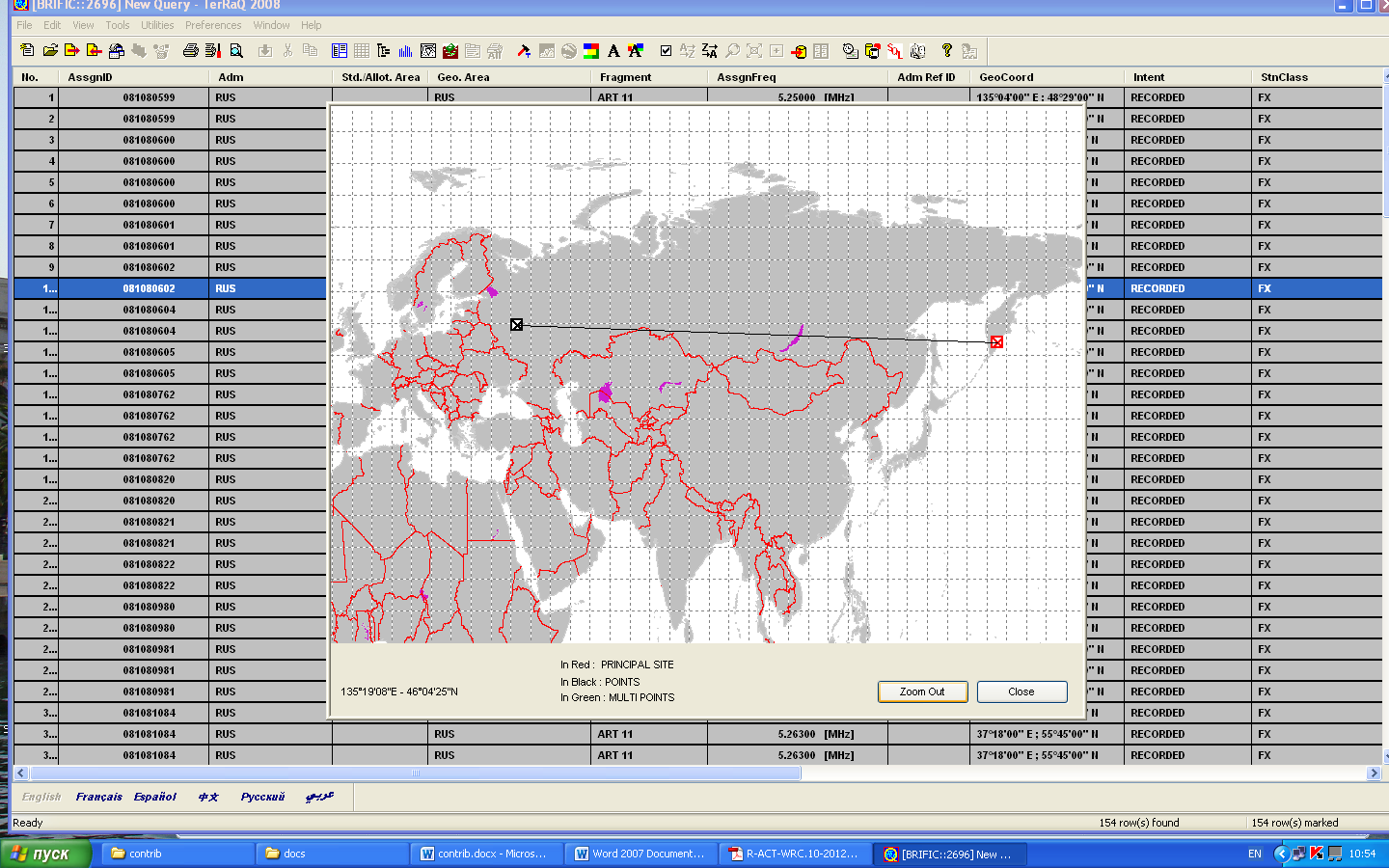


An effective (and in several cases single) solution of providing radiocommunication between these areas can be multihop link in the fixed and land mobile services. At such radio path signal transmission is provided by multiple reflection of electromagnetic wave from the earth surface and ionosphere.

An example of such a communication link is shown in Figure 2.

FigURE 2

An example of multihop link



Currently 557 frequency assignments are notified in Russia in this frequency band. Though this number of assignments does not reflect the actual occupancy of the frequency band 5 250‑5 450 kHz.

The Administration of the Russian Federation continues to submit the existing systems of the fixed and land mobile service to ITU Radiocommunication Bureau to provide protection of the existing frequency assignments.

Taking into account systems of the fixed and mobile services planning for submission the average density of the frequency assignments of medium and high power stations in the considered frequency band is 105 assignments per 10 kHz. It allows to conclude that in Russia approximately 2 000 frequency assignments of medium and high power stations providing communication at distance 3 000-7 000 km are used in the fixed and land mobile services.

Even more frequency assignments are used by stations of low power. According to preliminary evaluation more than 68 000 frequency assignments to stations of low power are operated in the considered frequency band.

# 3 Technical characteristics and protection criteria of fixed/mobile systems and systems of the radiolocation service operating in the frequency band 5 250-5 450 MHz

## 3.1 Technical characteristics and protection criteria of fixed systems

Antenna patterns used by fixed service systems are presented in Recommendation ITU-R F.162-3 “Use of directional transmitting antennas in the fixed service operating in bands below about 30 MHz”.

Protection criteria of the fixed service systems operating in the considered frequency band are presented in Recommendation ITU-R F.240-7 “Signal-to-interference protection ratios for various classes of emission in the fixed service below about 30 MHz” and in Recommendation ITU-R F.339-7 “Bandwidths, signal-to-noise ratios and fading allowances in complete systems”. The analysis of these Recommendations showed that depending from the system type and class of emission the required protection ratio can be changed from 1 dB to 60 dB.

The characteristics of the systems in the fixed service required for sharing studies between fixed service and stations of the amateur service are given in Recommendations ITU-R F.1761, ITU-R F.1762 and ITU‑R F.1821. In particularcharacteristics of the fixed service presented in Recommendation ITU-R F.1761 “Characteristics of HF fixed radiocommunication systems” are given in Table 3.1.

TABLE 3.1

Typical technical characteristics of HF systems

|  |  |
| --- | --- |
| Frequency band (MHz) | 2-30 |
| Type of emission | Analogue/digital |
| *System* |  |
| Channel bandwidth (kHz) | 2-6 |
| Modulation type | Single channel suppressed carrier, telephony and telegraphy |
| Type of operation | Simplex/duplex |
| Typical data rates | 2.4-9.6 kbit/s |
| Typical SINAD | 12 dB (voice only) |
| *Transmitter* |  |
| Tx power (dBW) | 22 |
| Path length (km) | 2 400 |
| Antenna gain (dBi) | 6 |
| Antenna height (m) (Relative to ground level) | 10-60 |
| Radiation pattern | Omnidirectional/directional |
| Antenna polarization | Vertical/horizontal |
| Total loss (dB) | 1 |
| *Receiver* |  |
| IF filter bandwidth (kHz) | 3-7 |
| Sensitivity (dBm) | –112 |
| Antenna gain (dBd) | 6 |
| Antenna pattern | Omnidirectional/directional (30° beamwidth) |

The analysis of Recommendations ITU-R F.1761, ITU-R F.1762 and ITU-R F.1821 showed that for various systems in the fixed service the required value of signal/noise ratio changes in wide range depending from the modulation type, operation mode etc. Therefore the following values of signal/noise ratio were used in the studies:

*–* [*S/N=*24 dB – for high-speed data transmission;

*–* *S/N=*21 dB – for analogue transmission of voice signal;

*– S/N=*8 dB – for digital transmission of voice signal.]

The selected values of signal/noise ratio correspond to the technical characteristics of the fixed adaptive system given in Table 4 of Recommendation ITU-R F.1761. In the studies it was assumed that power value of FS transmitter antenna is 37 dBW.

The data presented in Table 3.1 refer to radio paths of 2 400 km. In case of longer radio path it is required to increase transmitter power or to use higher antenna gain in order to provide operation of the system. For example for radio paths of 7 000 km (see Figure 2) transmitter output power in the fixed service station can reach 38 dBW. The receiver sensitivity is the same and determined by external noise.

## 3.2 Technical characteristics of land mobile systems

The typical technical characteristics of the land mobile systems operating in the considered frequency band are shown in Recommendation ITU-R M.1795 “Technical and operational characteristics of land mobile MF/HF systems”. The characteristics of base stations and mobile components of the HF systems in the considered frequency range are presented in Tables 2 and 3 below.

TABLE 3.2

Representative technical characteristics of land mobile systems   
in the bands between 2 and 30 MHz

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Group A | Group B | Group C | Group D | Group E |
| Type | Base station | Base station | Base station | Base station | Base station |
| Frequency (MHz) | 1.5-30 | 1.5-30 | 1.5-30 | 1.5-30 | 2-30 |
| Bandwidth (kHz) | 2.8 | 2.8 | 2.8 | 2.8 | 2-3 |
| Transmitter power (dBW) | 30-40 | 1-10 | 20-25 | 1-10 | 1-20 |
| Antenna gain (dBi) | 0 | 0 | 0 | 0 | –2.5-2.5 |
| Antenna height (m) | 10-60 | 10-60 | 10-60 | 10-60 | 10-60 |
| Antenna type | Co-linear, whip, dipole | | | Vee | Fan dipole |
| Polarization | Horizontal and vertical | | | | |
| Modulation | Analogue or digital, single-sideband suppressed carrier | | | | |
| Typical minimum path lengths (km) | 300-350 | | | | |

TABLE 3.3

Representative technical characteristics of mobile component of the land mobile system   
in the bands between 2 and 30 MHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Group F | Group G | | Group H | | Group I | Group J |
| Type | Mobile unit | Mobile unit | | Mobile unit | | Mobile unit | Mobile unit |
| Frequency (MHz) | 1.6-30 | 1.5-30 | | 1-30 | | 1.6-30 | 2-30 |
| Bandwidth (kHz) | 2-2.3 | 2.8-3 | | 2.7-3.6 | | 2-3 | 2-3 |
| Transmitter power (dBW) | 1-13 | 10-30 | | 7 | | 10-27 | 1-10 |
| Antenna gain (dBi) | –10-0 | 0-2 | | 2 | | 0-2 | –10-2 |
| Antenna height (m) | 3-10 | 3-10 | | 15 | | 3-10 | 10-20 |
| Antenna type | Whip | | | | | Vee | Whip |
| Polarization | Vertical | | Vertical and horizontal | | Vertical | Vertical and horizontal | Horizontal |
| Modulation | Analogue or digital, single-sideband suppressed carrier | | | | | | |
| Typical minimum path lengths (km) | 300-350 | | | | | | |

[TBD]

## 3.3 Technical characteristics of the maritime mobile systems

[TBD]

## 3.4 Technical characteristics of oceanographic radars

[TBD]

# 4 Technical characteristics of the amateur systems

[TBD]

# 5 Compatibility analysis of the amateur systems with the fixed, land mobile, radiolocation and maritime mobile systems

*Recommendation ITU-R P.533 and the associated software model were used for performing required sharing and compatibility studies.*

## 5.1 Compatibility of the amateur systems with the fixed systems

The compatibility analysis of stations in the amateur service with fixed communication links was carried out on the example of single-hop and multihop fixed communication links. Murmansk (68.98 North and 33.08 East) – Moscow (55.9 North, 37.6 East) link of 1 490 km was used in the analysis as a single-hop link and Petropavlovsk-Kamchatski (53 North, 158 East) – Moscow (55.9 North, 37.6 East) link of 6 800 km was used in the analysis as a multihop link. Depending from day time and season transmissions on this link can be either in two or three hops.

As possible interference source for single-hop link possible amateur communication links such as Warsaw-Moscow link of 1 155 km and Berlin-Moscow link of 1 615 km were considered. For multihop fixed communication link Astana-Moscow amateur link of 2 277 km and amateur link of 6 200 km connecting the point at the equator (0 degree North, 37.6 East) with Moscow through the meridian were considered as interference sources. Depending from season and day time Astana‑Moscow link can operate either in one hop or two-hop mode. Equator-Moscow link operates only in multihop mode.

In simulation it was assumed that the power of the amateur station transmitter is 20 dBW. The results presented below were obtained assuming that the minimum signal/noise ratio for the amateur station is equal to the minimum signal/noise ratio of the stations in the fixed service and is 8 dB.

The impact of the considered links of the amateur stations on the fixed link operation was determined in accordance with the following methodology:

*–* for the amateur station dependence of *S*/*N* [dB] ratio from day time and season was determined for the minimum and maximum sunspot numbers;

*–* for the fixed service link dependence of *S*/*N* [dB] ratio from day time and season was determined for the minimum and maximum sunspot numbers;

*–* dependence of signal/interference [*S*/*I*, dB] ratio in the fixed service link from day time and season was determined for different levels of solar activity;

*–* the obtained results of *S*/*I* were compared with the required value of *S*/*I* ratio and it was determined operation modes and time intervals when operation of the fixed service link is feasible.

The simulation results of interference impact to single-hop and multihop fixed communication links are presented below in Tables 5.1-5.20.

Table 5.1 presents the simulation results of propagation conditions on Petropavlovsk-Kamchatski-Moscow path depending from day time and season at low solar activity with 10 sunspots. Here and in next Table cells where the signal/noise ratio exceeds 24 dB are highlighted by green colour and the Table cells where the signal/noise ratio ranges from 21 dB to 24 dB are marked by light green colour and the table cells where the signal/noise ratio ranges from 8 dB to 21 dB are highlighted by blue colour. The Table cells where the signal/noise ratio is less than 8 dB (the operation of the fixed communication link is not feasible) are marked by red colour.

The analysis presented in Table 5.1 showed that in case of no interference from the amateur link operation of Petropavlovsk-Kamchatski-Moscow link is feasible almost at any season. The selection of signal type and its transmission time are determined by month when operation of the link should be ensured however for the worst case of propagation conditions digital voice transmission appears to be feasible.

Table 5.2 contains simulation results of propagation conditions on the Astana-Moscow amateur interfering link at low solar activity. Here the Table cells where the signal/noise ratio exceeds 8 dB are highlighted by yellow colour. The Table cells where the signal/noise ratio is less than 8 dB (the operation of the amateur communication link is not feasible) are highlighted by red colour. Comparing of the results presented in Tables 5.1 and 5.2 showed that time when operation of the amateur communication link is not feasible falls into time interval when operation of the fixed communication link is not feasible.

Table 5.3 presents the simulation results of the signal/interference ratio dependence from the day time and season at low solar activity. The signal/noise ratio value is calculated only for the time when the operation of the amateur communication link is feasible. For time intervals when the operation of the amateur communication link is not feasible values of signal/noise ratio from Table 5.1 were used.

The analysis of the results presented in Table 5.3 showed that in case of interference from the considered amateur communication link operation of the fixed communication link will be disabled almost at any day time. In case of interference caused by the amateur communication link data transmission between Petropavlovsk-Kamchatski and Moscow will be feasible only for digital voice transmission 2 hours per day during two months (January, February) per year.

Table 5.4 presents the simulation results of propagation conditions on the Equator-Moscow amateur communication link. It is shown that data transmission on this link is feasible mostly at the same time as operation of Petropavlovsk-Kamchatski-Moscow link. Therefore it can be expected that this amateur communication link can influence the operation of the fixed communication link.

[Table 5.1

Propagation conditions on Petropavlovsk-Kamchatski-Moscow link for 10 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Useful link: Petropavlovsk-Kamchatski-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 10 | | Signal/noise ratio, dB | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 22 | 18 | 15 | 13 | 11 | 3 | 0 | 10 | 15 | 16 | 20.5 | 25.5 | 29 | 30 | 34 | 29.5 | 29 | 29 | 29.5 | 31 | 31.5 | 31 | 25 | 24 | 22 |
| February | 17.5 | 13 | 10 | 8 | 1 | –8.5 | –14 | –6 | 6 | 8.5 | 12 | 18 | 24 | 27 | 29 | 33 | 29 | 29 | 29.5 | 32 | 36.5 | 31 | 26 | 22 | 17.5 |
| March | 14 | 5.5 | 6 | –5 | –17 | –28 | –32 | –19 | –9 | –2 | 2 | 7 | 12 | 19 | 23 | 28 | 31 | 31.3 | 33 | 30 | 33 | 31 | 28 | 22 | 14 |
| April | 3 | –3.5 | –10 | –21 | –40 | –59 | –58 | –40 | –25 | –13 | –5 | –1 | 4 | 10 | 17 | 23 | 27.5 | 29 | 34 | 29 | 27 | 24 | 19 | 11 | 3 |
| May | –7.5 | –15 | –33 | –46 | –79 | –88 | –89 | –80 | –56 | –34 | –45 | –34 | –25 | 1.5 | 10 | 17 | 22 | 26.5 | 26 | 23 | 20 | 15.5 | 5 | 2 | –7.5 |
| June | –33.5 | –42 | –75 | –96 | –117 | –126 | –126 | –115 | –92 | –55 | –70 | –56 | –42 | –28 | –15 | 4 | 12 | 12 | 11 | 12 | 8 | 4 | –8 | –18 | –33 |
| July | –12 | –29 | –34 | –79 | –89 | –96 | –95 | –84 | –60 | –34 | –19 | –4 | –30 | –18 | 8 | 13 | 24 | 22 | 19 | 15 | 15 | 7 | 4 | –2 | –12 |
| August | 0 | –11 | –16 | –30 | –44 | –71 | –71 | –47 | –30 | –16 | –8 | –4 | 0 | 8 | 13 | 21 | 23 | 26 | 26 | 22 | 19 | 14 | 7 | 0 | 0 |
| September | 4 | 5.5 | –8 | –19 | –25 | –46 | –46 | –37 | –22 | –10 | –2 | 2 | 9 | 16 | 21.5 | 28 | 32 | 32 | 32 | 31 | 28 | 26 | 21 | 11 | 4 |
| October | 17 | 10 | 10.5 | –1.5 | –11 | –18 | –23 | –11 | –2 | 2.5 | 8 | 13 | 18 | 23 | 26 | 28.5 | 31.5 | 33 | 33 | 32 | 31 | 30 | 27 | 23 | 17 |
| November | 20 | 15 | 16 | 17 | 6 | –2 | –4 | 4 | 12 | 13 | 14 | 21.5 | 25 | 28 | 32.5 | 29 | 30 | 30.5 | 30 | 30.5 | 31 | 30 | 26 | 22 | 20 |
| December | 22 | 33 | 15 | 18 | 26 | 20 | 16 | 18 | 21 | 23 | 27 | 24.5 | 28.5 | 38.5 | 8.5 | 3 | 22 | 28 | 29 | 35 | 35.5 | 35 | 33 | 28 | 22 |

Table 5.2

Propagation conditions on Astana-Moscow link for 10 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Interfering link: Astana-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 10 | | Signal/noise ratio, dB | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 42.5 | 42.5 | 44 | 41.5 | 34 | 25 | 19 | 8.5 | 5 | 7 | 16 | 22.5 | 26.5 | 33 | 37 | 37.5 | 41 | 44 | 43 | 42 | 41 | 40.5 | 41 | 41 | 42.5 |
| February | 45 | 46.5 | 44.5 | 39 | 26 | 20 | 12.5 | –1 | –5 | –2 | 4 | 15 | 22 | 27 | 30.5 | 38 | 39 | 40 | 41.5 | 42 | 42 | 41 | 39.5 | 42.5 | 45 |
| March | 47 | 46 | 41 | 34 | 22 | 13.5 | –3.5 | –13 | –17 | –12 | –7 | 8.5 | 14 | 20 | 26 | 34 | 36 | 37 | 38 | 40 | 41 | 41.5 | 42 | 47 | 47 |
| April | 44 | 42 | 34 | 24 | 17.5 | 1 | –9 | –17 | –29 | –28 | –12 | –6 | 2 | 18 | 23 | 32 | 37 | 38 | 38 | 38 | 39 | 42 | 44 | 46 | 44 |
| May | 40 | 36 | 26 | 18.5 | 3 | –8 | –21 | –29 | –32 | –31 | –27 | –12 | –7 | 3.5 | 20 | 25 | 33 | 36 | 36 | 36 | 36 | 39.5 | 40.5 | 40.5 | 40 |
| June | 34 | 26 | 20 | 2 | –9 | –23 | –29.5 | –34 | –36 | –36 | –35 | –29.5 | –16 | –5 | 6 | 21 | 22 | 32 | 38 | 38 | 38 | 38 | 38 | 38 | 34 |
| July | 38 | 34 | 25 | 11 | –0.5 | –11 | –24 | –30 | –32 | –31.5 | –27.5 | –15 | –8 | 3 | 18 | 23 | 32 | 34 | 35 | 36 | 37 | 38 | 38 | 38 | 38 |
| August | 41 | 39.5 | 28 | 22 | 13.5 | –4 | –13 | –26 | –30 | –28 | –14 | –8 | 0 | 16 | 22 | 31 | 33.5 | 34.5 | 35 | 37.5 | 38 | 38.5 | 39 | 40 | 41 |
| September | 47 | 44 | 38.5 | 25 | 18 | 8 | –10 | –16 | –18 | –16 | –10 | –1 | 13 | 21 | 27 | 34 | 38 | 38 | 38 | 39 | 40 | 42 | 44 | 46 | 47 |
| October | 46.5 | 45.5 | 40.5 | 33 | 24 | 16 | 3 | –3.5 | –6 | –3 | 9 | 15 | 21 | 26 | 34 | 38 | 38 | 38.5 | 39 | 39.5 | 40 | 41 | 42 | 46 | 46.5 |
| November | 46 | 47 | 43.5 | 38 | 28 | 23 | 17 | 7.5 | 4 | 11 | 16 | 21 | 26 | 34 | 38 | 39 | 40 | 41 | 42 | 42.5 | 40.5 | 41 | 41.5 | 44 | 46 |
| December | 43 | 46 | 46 | 44 | 39 | 28 | 25.5 | 20 | 17.5 | 19 | 23 | 28 | 35 | 39 | 40 | 44 | 46 | 45 | 44 | 43 | 41.5 | 41 | 41 | 41.5 | 43 |

Table 5.3

Propagation conditions on Petropavlovsk-Kamchatski-Moscow link for 10 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Petropavlovsk-Kamchatski-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Astana-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 10 | |  | | | Output power | | | 0.1 kW | | SSN | | 10 | |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | −20.5 | –24.5 | –29 | –28.5 | –23 | –22 | –19 | 1.5 | 15 | 16 | 4.5 | 3 | 2.5 | –3 | –3 | –8 | –12 | –15 | –13.5 | –11 | –9.5 | –9.5 | –16 | –17 | –20.5 |
| February | –27.5 | –33.5 | –34.5 | –31 | –25 | –28.5 | –26.5 | –6 | 6 | 8.5 | 12 | 3 | 2 | 0 | –1.5 | –5 | –10 | –11 | –12 | –10 | –5.5 | –10 | –13.5 | –20.5 | –27.5 |
| March | –33 | –40.5 | –35 | –39 | –39 | –41.5 | –32 | –19 | –9 | –2 | 2 | –1.5 | –2 | –1 | –3 | –6 | –5 | –5.7 | –5 | –10 | –8 | –10.5 | –14 | –25 | –33 |
| April | –41 | –45.5 | –44 | –45 | –57.5 | –59 | –58 | –40 | –25 | –13 | –5 | –1 | 4 | –8 | –6 | –9 | –9.5 | –9 | –4 | –9 | –12 | –18 | –25 | –35 | –41 |
| May | –47.5 | –51 | –59 | –64.5 | –79 | –88 | –89 | –80 | –56 | –34 | –45 | –34 | –25 | 1.5 | –10 | –8 | –11 | –9.5 | –10 | –13 | –16 | –24 | –35.5 | –38.5 | –47.5 |
| June | –67.5 | –68 | –95 | –96 | –117 | –126 | –126 | –115 | –92 | –55 | –70 | –56 | –42 | –28 | –15 | –17 | –10 | –20 | –27 | –26 | –30 | –34 | –46 | –56 | –67 |
| July | –50 | –63 | –59 | –90 | –89 | –96 | –95 | –84 | –60 | –34 | –19 | –4 | –30 | –18 | –10 | –10 | –8 | –12 | –16 | –21 | –22 | –31 | –34 | –40 | –50 |
| August | –41 | –50.5 | –44 | –52 | –57.5 | –71 | –71 | –47 | –30 | –16 | –8 | –4 | 0 | –8 | –9 | –10 | –10.5 | –8.5 | –9 | –15.5 | –19 | –24.5 | –32 | –40 | –41 |
| September | –43 | –38.5 | –46.5 | –44 | –43 | –54 | –46 | –37 | –22 | –10 | –2 | 2 | –4 | –5 | –5.5 | –6 | –6 | –6 | –6 | –8 | –12 | –16 | –23 | –35 | –43 |
| October | –29.5 | –35.5 | –30 | –34.5 | –35 | –34 | –23 | –11 | –2 | 2.5 | –1 | –2 | –3 | –3 | –8 | –9.5 | –6.5 | –5.5 | –6 | –7.5 | –9 | –11 | –15 | –23 | –29.5 |
| November | –26 | –32 | –27.5 | –21 | –22 | –25 | –21 | 4 | 12 | 2 | –2 | 0.5 | –1 | –6 | –5.5 | –10 | –10 | –10.5 | –12 | –12 | –9.5 | –11 | –15.5 | –22 | –26 |
| December | –21 | –13 | –31 | –26 | –13 | –8 | –9.5 | –2 | 3.5 | 4 | 4 | –3.5 | –6.5 | –0.5 | –31.5 | –41 | –24 | –17 | –15 | –8 | –6 | –6 | –8 | –13.5 | –21 |

Table 5.4

Propagation conditions on Equator-Moscow link for 10 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Equator-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 10 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 10.0 | 9.0 | 5.0 | 7.0 | 6.0 | –20.0 | –55.0 | –103.0 | –161.0 | –200.0 | –202.0 | –163.0 | –101.0 | –51.0 | –19.0 | 5.0 | 12.0 | 12.0 | 12.0 | 12.0 | 13.0 | 13.0 | 12.0 | 12.0 | 10.0 |
| February | 12.0 | 10.0 | 9.0 | 8.0 | –5.0 | –24.0 | –62.0 | –119.0 | –181.0 | –221.0 | –224.0 | –186.0 | –123.0 | –63.0 | –25.0 | –6.0 | 11.0 | 12.0 | 12.0 | 13.0 | 13.0 | 13.0 | 12.0 | 12.0 | 12.0 |
| March | 13.0 | 13.0 | 9.0 | 9.0 | –5.0 | –28.0 | –72.0 | –137.0 | –202.0 | –245.0 | –248.0 | –209.0 | –147.0 | –82.0 | –35.0 | –12.0 | 5.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 13.0 |
| April | 13.0 | 10.0 | 9.0 | 5.0 | –10.0 | –35.0 | –83.0 | –145.0 | –205.0 | –245.0 | –248.0 | –212.0 | –152.0 | –90.0 | –40.0 | –14.0 | 1.0 | 14.0 | 12.0 | 12.0 | 12.0 | 12.0 | 13.0 | 13.0 | 13.0 |
| May | 10.0 | 10.0 | 8.0 | –1.0 | –15.0 | –46.0 | –96.0 | –153.0 | –208.0 | –244.0 | –247.0 | –214.0 | –158.0 | –99.0 | –49.0 | –16.0 | –3.0 | 8.0 | 12.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 10.0 |
| June | 9.0 | 9.0 | 6.0 | –7.0 | –34.0 | –61.0 | –109.0 | –162.0 | –211.0 | –243.0 | –247.0 | –217.0 | –165.0 | –109.0 | –59.0 | –22.0 | –7.0 | 2.0 | 9.0 | 9.0 | 10.0 | 10.0 | 9.0 | 9.0 | 9.0 |
| July | 9.0 | 10.0 | 8.0 | –2.0 | –17.0 | –51.0 | –100.0 | –154.0 | –208.0 | –243.0 | –244.0 | –207.0 | –149.0 | –92.0 | –44.0 | –15.0 | –4.0 | 6.0 | 9.0 | 9.0 | 10.0 | 10.0 | 9.0 | 9.0 | 9.0 |
| August | 9.0 | 10.0 | 10.0 | 1.0 | –14.0 | –42.0 | –90.0 | –147.0 | –205.0 | –243.0 | –241.0 | –196.0 | –133.0 | –76.0 | –31.0 | –11.0 | 1.0 | 13.0 | 11.0 | 9.0 | 10.0 | 10.0 | 9.0 | 9.0 | 9.0 |
| September | 13.0 | 9.0 | 8.0 | 3.0 | –12.0 | –36.0 | –82.0 | –141.0 | –202.0 | –243.0 | –238.0 | –186.0 | –119.0 | –60.0 | –21.0 | –7.0 | 7.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 13.0 |
| October | 12.0 | 13.0 | 9.0 | 7.0 | –7.0 | –28.0 | –65.0 | –121.0 | –180.0 | –220.0 | –218.0 | –171.0 | –100.0 | –49.0 | –18.0 | –4.0 | 11.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| November | 12.0 | 9.0 | 8.0 | 8.0 | 4.0 | –23.0 | –56.0 | –104.0 | –161.0 | –200.0 | –199.0 | –156.0 | –92.0 | –45.0 | –16.0 | 6.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| December | 12.0 | 9.0 | 5.0 | 6.0 | 6.0 | –11.0 | –50.0 | –94.0 | –143.0 | –180.0 | –181.0 | –143.0 | –82.0 | –40.0 | –7.0 | 9.0 | 12.0 | 12.0 | 12.0 | 12.0 | 13.0 | 13.0 | 12.0 | 12.0 | 12.0 |

Table 5.5

Propagation conditions on Petropavlovsk-Kamchatski-Moscow link for 10 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Petropavlovsk-Kamchatski-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Equator-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 10 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 12.0 | 9.0 | 15.0 | 13.0 | 11.0 | 3.0 | 0.0 | 10.0 | 15.0 | 16.0 | 20.5 | 25.5 | 29.0 | 30.0 | 34.0 | 29.5 | 17.0 | 17.0 | 17.5 | 19.0 | 18.5 | 18.0 | 13.0 | 12.0 | 12.0 |
| February | 5.5 | 3.0 | 1.0 | 0.0 | 1.0 | –8.5 | –14.0 | –6.0 | 6.0 | 8.5 | 12.0 | 18.0 | 24.0 | 27.0 | 29.0 | 33.0 | 18.0 | 17.0 | 17.5 | 19.0 | 23.5 | 18.0 | 14.0 | 10.0 | 5.5 |
| March | 1.0 | –7.5 | –3.0 | –14.0 | –17.0 | –28.0 | –32.0 | –19.0 | –9.0 | –2.0 | 2.0 | 7.0 | 12.0 | 19.0 | 23.0 | 28.0 | 31.0 | 19.3 | 21.0 | 18.0 | 21.0 | 19.0 | 16.0 | 10.0 | 1.0 |
| April | –10.0 | –13.5 | –19.0 | –21.0 | –40.0 | –59.0 | –58.0 | –40.0 | –25.0 | –13.0 | –5.0 | –1.0 | 4.0 | 10.0 | 17.0 | 23.0 | 27.5 | 15.0 | 22.0 | 17.0 | 15.0 | 12.0 | 6.0 | –2.0 | –10.0 |
| May | –17.5 | –25.0 | –41.0 | –46.0 | –79.0 | –88.0 | –89.0 | –80.0 | –56.0 | –34.0 | –45.0 | –34.0 | –25.0 | 1.5 | 10.0 | 17.0 | 22.0 | 18.5 | 14.0 | 12.0 | 9.0 | 4.5 | –6.0 | –9.0 | –17.5 |
| June | –42.5 | –51.0 | –75.0 | –96.0 | –117.0 | –126.0 | –126.0 | –115.0 | –92.0 | –55.0 | –70.0 | –56.0 | –42.0 | –28.0 | –15.0 | 4.0 | 12.0 | 12.0 | 2.0 | 3.0 | –2.0 | –6.0 | –17.0 | –27.0 | –42.0 |
| July | –21.0 | –39.0 | –42.0 | –79.0 | –89.0 | –96.0 | –95.0 | –84.0 | –60.0 | –34.0 | –19.0 | –4.0 | –30.0 | –18.0 | 8.0 | 13.0 | 24.0 | 22.0 | 10.0 | 6.0 | 5.0 | –3.0 | –5.0 | –11.0 | –21.0 |
| August | –9.0 | –21.0 | –26.0 | –30.0 | –44.0 | –71.0 | –71.0 | –47.0 | –30.0 | –16.0 | –8.0 | –4.0 | 0.0 | 8.0 | 13.0 | 21.0 | 23.0 | 13.0 | 15.0 | 13.0 | 9.0 | 4.0 | –2.0 | –9.0 | –9.0 |
| September | –9.0 | –3.5 | –16.0 | –19.0 | –25.0 | –46.0 | –46.0 | –37.0 | –22.0 | –10.0 | –2.0 | 2.0 | 9.0 | 16.0 | 21.5 | 28.0 | 32.0 | 20.0 | 20.0 | 19.0 | 16.0 | 14.0 | 9.0 | –1.0 | –9.0 |
| October | 5.0 | –3.0 | 1.5 | –1.5 | –11.0 | –18.0 | –23.0 | –11.0 | –2.0 | 2.5 | 8.0 | 13.0 | 18.0 | 23.0 | 26.0 | 28.5 | 20.5 | 21.0 | 21.0 | 20.0 | 19.0 | 18.0 | 15.0 | 11.0 | 5.0 |
| November | 8.0 | 6.0 | 8.0 | 9.0 | 6.0 | –2.0 | –4.0 | 4.0 | 12.0 | 13.0 | 14.0 | 21.5 | 25.0 | 28.0 | 32.5 | 29.0 | 18.0 | 18.5 | 18.0 | 18.5 | 19.0 | 18.0 | 14.0 | 10.0 | 8.0 |
| December | 10.0 | 24.0 | 15.0 | 18.0 | 26.0 | 20.0 | 16.0 | 18.0 | 21.0 | 23.0 | 27.0 | 24.5 | 28.5 | 38.5 | 8.5 | –6.0 | 10.0 | 16.0 | 17.0 | 23.0 | 22.5 | 22.0 | 21.0 | 16.0 | 10.0 |

Table 5.6

Propagation conditions on Petropavlovsk-Kamchatski-Moscow link for 80 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Petropavlovsk-Kamchatski-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 80 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 16 | 12.5 | 9 | 13 | 6 | –3 | –7.5 | 1 | 8 | 9 | 9.5 | 19 | 25 | 27 | 28 | 35 | 31 | 30.5 | 30 | 31 | 34 | 27 | 24 | 22 | 17 |
| February | 9 | 3.5 | 6 | –3 | –13.5 | –21 | –28 | –19 | –6 | 5 | 4 | 10 | 17 | 22 | 24.5 | 27 | 28 | 28 | 29 | 36 | 31 | 23 | 22 | 16 | 9 |
| March | –1 | 0 | –8 | –1.5 | –30 | –46 | –55 | –49 | –22 | –5 | –8 | –3 | 5 | 11 | 19 | 23 | 27 | 27 | 36 | 31 | 28 | 24 | 19 | 9 | –1 |
| April | –4 | –17 | –25 | –39 | –54 | –66 | –62 | –57 | –44 | –29 | –20 | –8 | –4 | 2 | 11 | 18 | 23 | 30 | 28 | 23 | 17 | 17 | 18 | 10 | –4 |
| May | –24 | –33 | –49 | –124 | –135 | –142 | –143 | –135 | –68 | –49 | –33 | –25 | –10 | –9 | 1 | 11 | 20 | 19 | 17 | 10 | 17 | 10 | 0 | –14 | –25 |
| June | –52 | –136 | –158 | –178 | –170 | –198 | –192 | –190 | –172 | –80 | –128 | –106 | –82 | –60 | –38 | –20 | 2 | 4 | –2 | –6 | –4 | –14 | –26 | –36 | –52 |
| July | –30 | –47.3 | –125.6 | –141 | –154.2 | –161.5 | –161 | –150 | –112.6 | –54 | –36 | –26.6 | –11.6 | –9.5 | –0.3 | 14 | 14 | 15 | 12 | 6 | –7 | 3.5 | –6 | –22 | –30.6 |
| August | –21 | –28 | –42 | –59 | –68 | –129 | –126 | –67 | –50 | –42 | –26 | –49.5 | –34 | –0.5 | 8 | 15.5 | 20 | 23 | 21 | 15 | 6.4 | 8 | –1.3 | –5 | –21 |
| September | –12.5 | –19.6 | –26.5 | –41 | –56.4 | –71 | –61 | –56.4 | –42 | –27 | –16 | –7 | 0.5 | 8.6 | 16 | 22 | 26 | 33 | 28 | 26 | 27 | 18 | 10 | –1 | –12.5 |
| October | 1 | 4 | –8.5 | –16.6 | –29 | –42 | –46.5 | –29 | –16 | –8 | –1 | 5 | 11 | 17 | 22 | 26 | 28 | 28 | 34 | 30 | 17 | 17 | 17 | 9 | 1 |
| November | 12 | 7.4 | 11.4 | 1.5 | –5 | –14 | –17 | –6 | 3 | 6 | 10 | 15.5 | 20.5 | 24 | 26 | 30.5 | 28 | 28 | 29 | 36.5 | 30.5 | 24.6 | 22.5 | 18 | 12 |
| December | 21 | 18 | 15 | 14 | 17 | 12 | 5.6 | 15 | 16.6 | 17 | 20 | 25 | 29.5 | 31 | 29.5 | 29 | 30 | 29 | 30 | 31.6 | 31.5 | 32 | 22.5 | 23.5 | 21 |

Table 5.7

Propagation conditions on Astana-Moscow link for 80 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Астана-Москва, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 80 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 47 | 47 | 47 | 40 | 31.5 | 22 | 15 | 1 | –6 | –6 | 7 | 15 | 23 | 28 | 37 | 38 | 40 | 42 | 43 | 42.6 | 42 | 41 | 40 | 42 | 47 |
| February | 45 | 47 | 43 | 33.6 | 23 | 14.4 | –1 | –14 | –21 | –20 | –12.5 | 6 | 15 | 23 | 28 | 36.6 | 37.6 | 39 | 42.3 | 43 | 43 | 41 | 41 | 42 | 45 |
| March | 41 | 40.5 | 38 | 24 | 17 | 5 | –16 | –25.5 | –51 | –49 | –40 | –14 | 4.4 | 14 | 22 | 32 | 36 | 36 | 36 | 37 | 37.5 | 39 | 39.4 | 40 | 41 |
| April | 39 | 37 | 31 | 18.5 | 8.6 | –13 | –34 | –48 | –55 | –54 | –46 | –33 | –1 | 8 | 17 | 25 | 34 | 36 | 36 | 36 | 36.5 | 38.5 | 39 | 39 | 39 |
| May | 36 | 31.5 | 21 | 10.3 | –12.5 | –33 | –45.6 | –55.4 | –69 | –68.2 | –54 | –44 | –31 | –9.3 | 11.3 | 20.5 | 30 | 35 | 35.6 | 36 | 36 | 37.8 | 38 | 38 | 36 |
| June | 31 | 21.4 | 13 | –13 | –36 | –48 | –55.6 | –70 | –75 | –75.5 | –71 | –55 | –47 | –32 | –8.5 | 13.5 | 20 | 29 | 33.6 | 34.7 | 35 | 36 | 36 | 34.4 | 31 |
| July | 34 | 25 | 19.4 | –1.4 | –16 | –38.3 | –51 | –68 | –73.4 | –71.4 | –55 | –45 | –33 | –13 | 9.6 | 18.5 | 27 | 32 | 34 | 34.6 | 35 | 35.7 | 35.7 | 35.7 | 34 |
| August | 37 | 34.3 | 24 | 16 | 5 | –28.5 | –45 | –56.5 | –61 | –58 | –48.4 | –34.2 | –15 | 7 | 15 | 22.5 | 30 | 33 | 34.2 | 34.7 | 35 | 36 | 36.3 | 36.4 | 37.2 |
| September | 40 | 39 | 33 | 19 | 8.4 | –13 | –25.6 | –54 | –59.3 | –54 | –41 | –13 | 4 | 12.3 | 20.6 | 31 | 36 | 36.5 | 36 | 36 | 36.3 | 38.4 | 39 | 40 | 40 |
| October | 41.7 | 40.5 | 37 | 24 | 17 | 7 | –10.5 | –21.6 | –26.3 | –22.5 | –13.8 | 5 | 12.6 | 20.5 | 26 | 34.5 | 36.6 | 36.6 | 36.2 | 36.4 | 36.5 | 38.3 | 39 | 40 | 42 |
| November | 42 | 43 | 40 | 33 | 24 | 17.4 | 10 | –4 | –11 | –9 | 5 | 13.4 | 20.6 | 26.3 | 34.7 | 37 | 37 | 38 | 37.6 | 37.4 | 37.1 | 39 | 39 | 40 | 42 |
| December | 42.3 | 45 | 44.3 | 38.4 | 34.3 | 25.5 | 22 | 15 | 10.2 | 10 | 15 | 22.2 | 27.3 | 36.3 | 37.6 | 37.7 | 38 | 40.3 | 42 | 42 | 41 | 39.6 | 39.4 | 40 | 42.3 |

Table 5.8

Propagation conditions on Petropavlovsk-Kamchatski-Moscow link for 80 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Petropavlovsk-Kamchatski-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Астана-Москва, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 80 | |  | | | Output power | | | 0.1 kW | | SSN | | 80 | |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | –31 | –34.5 | –38 | –27 | –25.5 | –25 | –22.5 | 1 | 8 | 9 | 9.5 | 4 | 2 | –1 | –9 | –3 | –9 | –11.5 | –13 | –11.6 | –8 | –14 | –16 | –20 | –30 |
| February | –36 | –43.5 | –37 | –36.6 | –36.5 | –35.4 | –28 | –19 | –6 | 5 | 4 | 10 | 2 | –1 | –3.5 | –9.6 | –9.6 | –11 | –13.3 | –7 | –12 | –18 | –19 | –26 | –36 |
| March | –42 | –40.5 | –46 | –25.5 | –47 | –46 | –55 | –49 | –22 | –5 | –8 | –3 | 5 | –3 | –3 | –9 | –9 | –9 | 0 | –6 | –9.5 | –15 | –20.4 | –31 | –42 |
| April | –43 | –54 | –56 | –57.5 | –62.6 | –66 | –62 | –57 | –44 | –29 | –20 | –8 | –4 | –6 | –6 | –7 | –11 | –6 | –8 | –13 | –19.5 | –21.5 | –21 | –29 | –43 |
| May | –60 | –64.5 | –70 | –134.3 | –135 | –142 | –143 | –135 | –68 | –49 | –33 | –25 | –10 | –9 | –10.3 | –9.5 | –10 | –16 | –18.6 | –26 | –19 | –27.8 | –38 | –52 | –61 |
| June | –83 | –157.4 | –171 | –178 | –170 | –198 | –192 | –190 | –172 | –80 | –128 | –106 | –82 | –60 | –38 | –33.5 | –18 | –25 | –35.6 | –40.7 | –39 | –50 | –62 | –70.4 | –83 |
| July | –64 | –72.3 | –145 | –141 | –154.2 | –161.5 | –161 | –150 | –112.6 | –54 | –36 | –26.6 | –11.6 | –9.5 | –9.9 | –4.5 | –13 | –17 | –22 | –28.6 | –42 | –32.2 | –41.7 | –57.7 | –64.6 |
| August | –58 | –62.3 | –66 | –75 | –68 | –129 | –126 | –67 | –50 | –42 | –26 | –49.5 | –34 | –0.5 | –7 | –7 | –10 | –10 | –13.2 | –19.7 | –28.6 | –28 | –37.6 | –41.4 | –58.2 |
| September | –52.5 | –58.6 | –59.5 | –60 | –64.8 | –71 | –61 | –56.4 | –42 | –27 | –16 | –7 | 0.5 | –3.7 | –4.6 | –9 | –10 | –3.5 | –8 | –10 | –9.3 | –20.4 | –29 | –41 | –52.5 |
| October | –40.7 | –36.5 | –45.5 | –40.6 | –46 | –42 | –46.5 | –29 | –16 | –8 | –1 | 5 | –1.6 | –3.5 | –4 | –8.5 | –8.6 | –8.6 | –2.2 | –6.4 | –19.5 | –21.3 | –22 | –31 | –41 |
| November | –30 | –35.6 | –28.6 | –31.5 | –29 | –31.4 | –27 | –6 | 3 | 6 | 10 | 2.1 | –0.1 | –2.3 | –8.7 | –6.5 | –9 | –10 | –8.6 | –0.9 | –6.6 | –14.4 | –16.5 | –22 | –30 |
| December | –21.3 | –27 | –29.3 | –24.4 | –17.3 | –13.5 | –16.4 | 0 | 6.4 | 7 | 5 | 2.8 | 2.2 | –5.3 | –8.1 | –8.7 | –8 | –11.3 | –12 | –10.4 | –9.5 | –7.6 | –16.9 | –16.5 | –21.3 |

Table 5.9

Propagation conditions on Equator-Moscow link for 80 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Equator-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 80 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 12.0 | 12.0 | 10.0 | 9.0 | 3.0 | –28.0 | –76.0 | –159.0 | –244.0 | –301.0 | –302.0 | –245.0 | –130.0 | –74.0 | –30.0 | –3.0 | 11.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 12.0 |
| February | 12.0 | 12.0 | 20.0 | 9.0 | –3.0 | –35.0 | –91.0 | –177.0 | –267.0 | –330.0 | –335.0 | –276.0 | –187.0 | –98.0 | –42.0 | –14.0 | 6.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 12.0 |
| March | 20.0 | 20.0 | 20.0 | 7.0 | –11.0 | –43.0 | –107.0 | –197.0 | –294.0 | –365.0 | –373.0 | –313.0 | –218.0 | –129.0 | –59.0 | –20.0 | –2.0 | 11.0 | 12.0 | 12.0 | 12.0 | 13.0 | 13.0 | 13.0 | 20.0 |
| April | 20.0 | 20.0 | 10.0 | 0.0 | –18.0 | –57.0 | –127.0 | –215.0 | –307.0 | –370.0 | –373.0 | –316.0 | –228.0 | –141.0 | –72.0 | –26.0 | –7.0 | 8.0 | 19.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| May | 20.0 | 11.0 | 11.0 | –8.0 | –27.0 | –77.0 | –148.0 | –236.0 | –321.0 | –374.0 | –373.0 | –320.0 | –238.0 | –155.0 | –88.0 | –37.0 | –10.0 | 3.0 | 13.0 | 12.0 | 12.0 | 12.0 | 20.0 | 20.0 | 20.0 |
| June | 9.0 | 8.0 | 5.0 | –17.0 | –55.0 | –100.0 | –173.0 | –258.0 | –335.0 | –379.0 | –373.0 | –323.0 | –249.0 | –172.0 | –105.0 | –52.0 | –16.0 | –2.0 | 7.0 | 17.0 | 11.0 | 10.0 | 9.0 | 9.0 | 9.0 |
| July | 19.0 | 10.0 | 9.0 | –11.0 | –32.0 | –86.0 | –159.0 | –248.0 | –333.0 | –382.0 | –372.0 | –311.0 | –228.0 | –150.0 | –87.0 | –37.0 | –11.0 | 2.0 | 12.0 | 11.0 | 11.0 | 11.0 | 11.0 | 18.0 | 19.0 |
| August | 19.0 | 19.0 | 13.0 | –6.0 | –23.0 | –72.0 | –146.0 | –239.0 | –332.0 | –385.0 | –370.0 | –299.0 | –209.0 | –131.0 | –69.0 | –25.0 | –8.0 | 6.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 18.0 | 19.0 |
| September | 20.0 | 20.0 | 10.0 | –2.0 | –18.0 | –60.0 | –134.0 | –230.0 | –330.0 | –388.0 | –368.0 | –287.0 | –191.0 | –112.0 | –54.0 | –18.0 | –1.0 | 11.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 20.0 | 20.0 |
| October | 20.0 | 20.0 | 20.0 | 3.0 | –13.0 | –45.0 | –107.0 | –197.0 | –288.0 | –344.0 | –332.0 | –260.0 | –169.0 | –89.0 | –38.0 | –13.0 | 5.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 20.0 |
| November | 12.0 | 13.0 | 10.0 | 11.0 | –2.0 | –34.0 | –87.0 | –168.0 | –253.0 | –307.0 | –300.0 | –237.0 | –127.0 | –71.0 | –29.0 | –4.0 | 10.0 | 12.0 | 12.0 | 12.0 | 12.0 | 20.0 | 12.0 | 12.0 | 12.0 |
| December | 12.0 | 12.0 | 12.0 | 11.0 | 4.0 | –20.0 | –72.0 | –133.0 | –223.0 | –275.0 | –272.0 | –216.0 | –119.0 | –63.0 | –18.0 | 4.0 | 12.0 | 12.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 12.0 | 12.0 |

Table 5.10

Propagation conditions on Petropavlovsk-Kamchatski-Moscow link for 80 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Petropavlovsk-Kamchatski-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Equator-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 80 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 4.0 | 0.5 | –1.0 | 4.0 | 6.0 | –3.0 | –7.5 | 1.0 | 8.0 | 9.0 | 9.5 | 19.0 | 25.0 | 27.0 | 28.0 | 35.0 | 20.0 | 17.5 | 17.0 | 18.0 | 21.0 | 14.0 | 11.0 | 9.0 | 5.0 |
| February | –3.0 | –8.5 | –14.0 | –12.0 | –13.5 | –21.0 | –28.0 | –19.0 | –6.0 | 5.0 | 4.0 | 10.0 | 17.0 | 22.0 | 24.5 | 27.0 | 28.0 | 15.0 | 16.0 | 23.0 | 18.0 | 10.0 | 9.0 | 3.0 | –3.0 |
| March | –21.0 | –20.0 | –28.0 | –1.5 | –30.0 | –46.0 | –55.0 | –49.0 | –22.0 | –5.0 | –8.0 | –3.0 | 5.0 | 11.0 | 19.0 | 23.0 | 27.0 | 16.0 | 24.0 | 19.0 | 16.0 | 11.0 | 6.0 | –4.0 | –21.0 |
| April | –24.0 | –37.0 | –35.0 | –39.0 | –54.0 | –66.0 | –62.0 | –57.0 | –44.0 | –29.0 | –20.0 | –8.0 | –4.0 | 2.0 | 11.0 | 18.0 | 23.0 | 22.0 | 9.0 | 3.0 | –3.0 | –3.0 | –2.0 | –10.0 | –24.0 |
| May | –44.0 | –44.0 | –60.0 | –124.0 | –135.0 | –142.0 | –143.0 | –135.0 | –68.0 | –49.0 | –33.0 | –25.0 | –10.0 | –9.0 | 1.0 | 11.0 | 20.0 | 19.0 | 4.0 | –2.0 | 5.0 | –2.0 | –20.0 | –34.0 | –45.0 |
| June | –61.0 | –144.0 | –158.0 | –178.0 | –170.0 | –198.0 | –192.0 | –190.0 | –172.0 | –80.0 | –128.0 | –106.0 | –82.0 | –60.0 | –38.0 | –20.0 | 2.0 | 4.0 | –2.0 | –23.0 | –15.0 | –24.0 | –35.0 | –45.0 | –61.0 |
| July | –49.0 | –57.3 | –134.6 | –141.0 | –154.2 | –161.5 | –161.0 | –150.0 | –112.6 | –54.0 | –36.0 | –26.6 | –11.6 | –9.5 | –0.3 | 14.0 | 14.0 | 15.0 | 0.0 | –5.0 | –18.0 | –7.5 | –17.0 | –40.0 | –49.6 |
| August | –40.0 | –47.0 | –55.0 | –59.0 | –68.0 | –129.0 | –126.0 | –67.0 | –50.0 | –42.0 | –26.0 | –49.5 | –34.0 | –0.5 | 8.0 | 15.5 | 20.0 | 23.0 | 10.0 | 4.0 | –4.6 | –3.0 | –12.3 | –23.0 | –40.0 |
| September | –32.5 | –39.6 | –36.5 | –41.0 | –56.4 | –71.0 | –61.0 | –56.4 | –42.0 | –27.0 | –16.0 | –7.0 | 0.5 | 8.6 | 16.0 | 22.0 | 26.0 | 22.0 | 16.0 | 14.0 | 15.0 | 6.0 | –2.0 | –21.0 | –32.5 |
| October | –19.0 | –16.0 | –28.5 | –16.6 | –29.0 | –42.0 | –46.5 | –29.0 | –16.0 | –8.0 | –1.0 | 5.0 | 11.0 | 17.0 | 22.0 | 26.0 | 28.0 | 16.0 | 22.0 | 18.0 | 5.0 | 5.0 | 5.0 | –3.0 | –19.0 |
| November | 0.0 | –5.6 | 1.4 | –9.5 | –5.0 | –14.0 | –17.0 | –6.0 | 3.0 | 6.0 | 10.0 | 15.5 | 20.5 | 24.0 | 26.0 | 30.5 | 18.0 | 16.0 | 17.0 | 24.5 | 18.5 | 4.6 | 10.5 | 6.0 | 0.0 |
| December | 9.0 | 6.0 | 3.0 | 3.0 | 17.0 | 12.0 | 5.6 | 15.0 | 16.6 | 17.0 | 20.0 | 25.0 | 29.5 | 31.0 | 29.5 | 29.0 | 18.0 | 17.0 | 17.0 | 18.6 | 18.5 | 19.0 | 9.5 | 11.5 | 9.0 |

Table 5.11

Propagation conditions on Murmansk-Moscow link for 10 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Murmansk-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 10 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 66.5 | 65.5 | 56 | 54 | 58 | 64 | 63 | 55 | 51.5 | 49.5 | 49.5 | 52 | 56 | 59.5 | 62.5 | 67 | 56 | 64 | 64 | 65 | 66.5 | 67 | 67 | 67 | 66.5 |
| February | 65.5 | 67.7 | 52 | 53.5 | 61 | 63 | 59.5 | 47 | 47 | 45 | 45.3 | 47.5 | 50 | 56 | 58 | 63.5 | 67.5 | 66 | 65 | 64.5 | 65.5 | 65.5 | 66.5 | 66.5 | 65.5 |
| March | 57.5 | 57.3 | 57 | 63.5 | 66 | 61.5 | 51.5 | 41 | 37 | 34.5 | 35 | 39 | 43.5 | 47 | 52 | 56 | 58 | 58.5 | 62 | 63 | 62.5 | 61.5 | 61.5 | 60.5 | 57.5 |
| April | 65.5 | 66 | 65.5 | 66 | 65 | 55 | 43.5 | 37 | 35 | 31.5 | 32 | 37 | 39 | 43 | 50 | 53 | 57 | 57.5 | 58 | 60 | 63 | 62.7 | 62 | 65 | 65.5 |
| May | 67.5 | 69.5 | 65 | 63 | 51.5 | 42 | 37.5 | 32 | 31 | 29 | 29 | 33 | 34 | 39 | 41.5 | 46 | 54 | 56 | 57.5 | 57 | 56.5 | 58 | 60 | 67 | 67.5 |
| June | 66.5 | 66 | 64 | 51.5 | 44 | 36.5 | 32 | 29 | 26 | 25 | 25.5 | 25.5 | 28.5 | 31 | 32.5 | 38 | 42 | 49.5 | 52 | 54 | 56 | 56 | 57 | 62 | 66.5 |
| July | 65.5 | 67 | 66.5 | 64.7 | 55 | 47.5 | 41.5 | 37.5 | 34 | 32.5 | 32 | 33 | 36 | 40 | 40.5 | 43 | 51 | 52 | 55 | 54.3 | 58 | 59.5 | 62.5 | 64.5 | 65.5 |
| August | 65.5 | 66 | 68 | 66.5 | 65 | 57 | 43 | 37.5 | 34.5 | 33 | 33.3 | 34.5 | 38 | 41.5 | 42.5 | 52 | 53 | 53.5 | 54 | 54.5 | 59.5 | 63 | 62.5 | 64 | 65.5 |
| September | 58.5 | 58 | 56.5 | 65 | 64 | 57.5 | 44 | 38 | 34 | 33 | 34 | 48.5 | 42 | 46.5 | 52 | 56 | 59 | 58 | 59 | 61.5 | 62.5 | 62 | 61 | 60.5 | 58.5 |
| October | 58.5 | 57 | 46.5 | 63.5 | 65.5 | 62 | 50.5 | 42.5 | 41.7 | 40.5 | 41 | 45 | 48 | 54.5 | 55 | 58.5 | 59.5 | 61 | 64 | 63.5 | 62.5 | 61.5 | 61 | 62 | 58.5 |
| November | 61 | 56.5 | 52 | 53.8 | 63 | 62.5 | 58 | 50.3 | 47 | 45 | 45.3 | 52 | 55 | 58 | 60 | 65 | 64 | 63 | 62 | 61.5 | 61 | 61.2 | 61.5 | 65 | 61 |
| December | 65.5 | 58.5 | 49 | 44 | 50 | 46 | 64 | 61 | 59 | 56.5 | 56 | 58 | 61 | 66.5 | 67.5 | 66.5 | 58 | 54 | 54.5 | 57.5 | 62 | 65 | 65.7 | 65.7 | 65.6 |

Table 5.12

Propagation conditions on Warsaw-Moscow link for 10 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Warsaw-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 10 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 53 | 52 | 48 | 45 | 43 | 52 | 54 | 46 | 40 | 32 | 31 | 32.5 | 39 | 43 | 45 | 54.5 | 54 | 52 | 52 | 52.5 | 52.5 | 53 | 53.2 | 53.5 | 53 |
| February | 52 | 47 | 45 | 42.5 | 44 | 52.5 | 52 | 40.5 | 31.5 | 27 | 25 | 28.5 | 31 | 39.5 | 43 | 47.5 | 51.5 | 53 | 53.5 | 53 | 53 | 48 | 52 | 52 | 52 |
| March | 46 | 43.5 | 42 | 45 | 53 | 52 | 44.5 | 36 | 23 | 18 | 17.5 | 19 | 22.5 | 35 | 37.5 | 41.5 | 43 | 48 | 52 | 52.5 | 52 | 50.5 | 49.5 | 48 | 46 |
| April | 47.5 | 46.5 | 48 | 53 | 54 | 50 | 42.5 | 28 | 24 | 19.5 | 18.5 | 20.5 | 23 | 27 | 37.5 | 41 | 44 | 46 | 48 | 51 | 52 | 51.5 | 51.2 | 52.5 | 47.5 |
| May | 54 | 54 | 53.5 | 54 | 52.5 | 37 | 31 | 25 | 21 | 17.5 | 17 | 19 | 22 | 25 | 29 | 33 | 42 | 45 | 45 | 45.5 | 46 | 48 | 52.5 | 53 | 54 |
| June | 52.5 | 53 | 54 | 52 | 48 | 33 | 27 | 22 | 19 | 15.5 | 15 | 15.5 | 20 | 26 | 28 | 31 | 33 | 41 | 43 | 43 | 44.5 | 45 | 48 | 52 | 52.5 |
| July | 52.5 | 53 | 53.5 | 54 | 52 | 41 | 34 | 28 | 24 | 20 | 18 | 20 | 25 | 30 | 32 | 37 | 44.5 | 44.5 | 43 | 43.5 | 44.5 | 49 | 51.5 | 52 | 52.5 |
| August | 52 | 51.8 | 52.5 | 54 | 53 | 51 | 34 | 28.5 | 23 | 20 | 19.5 | 20 | 22.5 | 32.5 | 44 | 43.5 | 42 | 42 | 42.5 | 43 | 46 | 51.5 | 50.5 | 51 | 52 |
| September | 43.5 | 40.5 | 38 | 44.5 | 54 | 50.5 | 43 | 30.5 | 21 | 18 | 18 | 20 | 22.5 | 36.5 | 39.5 | 44 | 46 | 47 | 49 | 51.5 | 51.4 | 51 | 50 | 46 | 43.5 |
| October | 48 | 46 | 44.5 | 45.5 | 52.5 | 51.5 | 42.5 | 35.5 | 28.5 | 25 | 24.5 | 27 | 45.5 | 38.5 | 41 | 43 | 45.5 | 50 | 53 | 52.5 | 51 | 50.5 | 50 | 51.8 | 48 |
| November | 52.5 | 48 | 45.5 | 43.5 | 46.5 | 52 | 51 | 41 | 38 | 31 | 30 | 36.5 | 38.5 | 41 | 43.5 | 49 | 52 | 52 | 51 | 46 | 44 | 45 | 47 | 51 | 52.5 |
| December | 52.5 | 52 | 46 | 43 | 41 | 51.5 | 53 | 52.5 | 44 | 40.5 | 35 | 40.8 | 43.5 | 47.5 | 54 | 54 | 52.5 | 43.5 | 40.5 | 41 | 43.5 | 47 | 52.5 | 52.6 | 52.5 |

Table 5.13

Propagation conditions on Murmansk-Moscow link for 10 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Murmansk-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Warsaw-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 10 | |  | | | Output power | | | 0.1 kW | | SSN | | 10 | |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 13.5 | 13.5 | 8 | 9 | 15 | 12 | 9 | 9 | 11.5 | 17.5 | 18.5 | 19.5 | 17 | 16.5 | 17.5 | 12.5 | 2 | 12 | 12 | 12.5 | 14 | 14 | 13.8 | 13.5 | 13.5 |
| February | 13.5 | 20.7 | 7 | 11 | 17 | 10.5 | 7.5 | 6.5 | 15.5 | 18 | 20.3 | 19 | 19 | 16.5 | 15 | 16 | 16 | 13 | 11.5 | 11.5 | 12.5 | 17.5 | 14.5 | 14.5 | 13.5 |
| March | 11.5 | 13.8 | 15 | 18.5 | 13 | 9.5 | 7 | 5 | 14 | 16.5 | 17.5 | 20 | 21 | 12 | 14.5 | 14.5 | 15 | 10.5 | 10 | 10.5 | 10.5 | 11 | 12 | 12.5 | 11.5 |
| April | 18 | 19.5 | 17.5 | 13 | 11 | 5 | 1 | 9 | 11 | 12 | 13.5 | 16.5 | 16 | 16 | 12.5 | 12 | 13 | 11.5 | 10 | 9 | 11 | 11.2 | 10.8 | 12.5 | 18 |
| May | 13.5 | 15.5 | 11.5 | 9 | -1 | 5 | 6.5 | 7 | 10 | 11.5 | 12 | 14 | 12 | 14 | 12.5 | 13 | 12 | 11 | 12.5 | 11.5 | 10.5 | 10 | 7.5 | 14 | 13.5 |
| June | 14 | 13 | 10 | -0.5 | -4 | 3.5 | 5 | 7 | 7 | 9.5 | 10.5 | 10 | 8.5 | 5 | 4.5 | 7 | 9 | 8.5 | 9 | 11 | 11.5 | 11 | 9 | 10 | 14 |
| July | 13 | 14 | 13 | 10.7 | 3 | 6.5 | 7.5 | 9.5 | 10 | 12.5 | 14 | 13 | 11 | 10 | 8.5 | 6 | 6.5 | 7.5 | 12 | 10.8 | 13.5 | 10.5 | 11 | 12.5 | 13 |
| August | 13.5 | 14.2 | 15.5 | 12.5 | 12 | 6 | 9 | 9 | 11.5 | 13 | 13.8 | 14.5 |  | 9 | -1.5 | 8.5 | 11 | 11.5 | 11.5 | 11.5 | 13.5 | 11.5 | 12 | 13 | 13.5 |
| September | 15 | 17.5 | 18.5 | 20.5 | 10 | 7 | 1 | 7.5 | 13 | 15 | 16 | 28.5 | 19.5 | 10 | 12.5 | 12 | 13 | 11 | 10 | 10 | 11.1 | 11 | 11 | 14.5 | 15 |
| October | 10.5 | 11 | 2 | 18 | 13 | 10.5 | 8 | 7 | 13.2 | 15.5 | 16.5 | 18 | 2.5 | 16 | 14 | 15.5 | 14 | 11 | 11 | 11 | 11.5 | 11 | 11 | 10.2 | 10.5 |
| November | 8.5 | 8.5 | 6.5 | 10.3 | 16.5 | 10.5 | 7 | 9.3 | 9 | 14 | 15.3 | 15.5 | 16.5 | 17 | 16.5 | 16 | 12 | 11 | 11 | 15.5 | 17 | 16.2 | 14.5 | 14 | 8.5 |
| December | 13 | 6.5 | 3 | 1 | 9 | -5.5 | 11 | 8.5 | 15 | 16 | 21 | 17.2 | 17.5 | 19 | 13.5 | 12.5 | 5.5 | 10.5 | 14 | 16.5 | 18.5 | 18 | 13.2 | 13.1 | 13.1 |

Table 5.14

Propagation conditions on Berlin-Moscow link for 10 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Berlin-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 10 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 50.5 | 50.4 | 50 | 49.8 | 49.1 | 49.6 | 50.2 | 38.5 | 33 | 27.7 | 25 | 26.8 | 30.5 | 35 | 39 | 42.5 | 49 | 50 | 49.8 | 49.5 | 50.2 | 50.3 | 50.4 | 50.4 | 50.5 |
| February | 50.5 | 50 | 49.5 | 49 | 49.5 | 50.5 | 44.4 | 31.5 | 26 | 16 | 14 | 16 | 24 | 29 | 33 | 39.5 | 43.5 | 46 | 50 | 50 | 50.5 | 50.5 | 50.5 | 50.5 | 50.5 |
| March | 49.9 | 50.1 | 49.5 | 49.5 | 50.5 | 49 | 36 | 25 | 14 | 9 | 8 | 10 | 12 | 17 | 26 | 32.5 | 39 | 41 | 42 | 46 | 48.5 | 48.5 | 48.5 | 50 | 49.9 |
| April | 50 | 50.5 | 50.5 | 51 | 50.5 | 39 | 29.2 | 21 | 10 | –4 | –6 | –4 | –2 | 12 | 21 | 29 | 36.5 | 41 | 41 | 42 | 43 | 48 | 49 | 50.2 | 50 |
| May | 50.5 | 51 | 51.5 | 50 | 42.5 | 29.8 | 22 | 11 | –2.5 | –7 | –8 | –7 | –4.5 | –1 | 12.5 | 24 | 34 | 39 | 41.5 | 41 | 40.5 | 41 | 41.5 | 48 | 50.5 |
| June | 46 | 48 | 49.8 | 43.5 | 37.5 | 25 | 12 | –2 | –6 | –9 | –11 | –10.5 | –9.5 | –5.5 | –3 | 11.5 | 22 | 32 | 37 | 39 | 38.8 | 39 | 39.5 | 42 | 46 |
| July | 49 | 49.5 | 51 | 48 | 41 | 31 | 22 | 10 | –3 | –7 | –8.5 | –8 | –6 | –2 | 10 | 22 | 29 | 36 | 38.5 | 38 | 39 | 40 | 41.5 | 47 | 49 |
| August | 49 | 50 | 50.5 | 51.5 | 49 | 39 | 26 | 15 | –1 | –6 | –7 | –6.5 | –4 | 10 | 14 | 28 | 34 | 37 | 37 | 37 | 39 | 40 | 46 | 48 | 48.5 |
| September | 49 | 49 | 48.6 | 49 | 51 | 41 | 30 | 20.5 | 9.5 | 8 | 7 | –2 | 11 | 14 | 27 | 36 | 40 | 41 | 41 | 42 | 44 | 49 | 48.5 | 49.5 | 49 |
| October | 50 | 50.5 | 50 | 49.7 | 51 | 47 | 37 | 29 | 23 | 13.5 | 12 | 15 | 22 | 28 | 31 | 38 | 41 | 42.5 | 43.5 | 45.5 | 48 | 48 | 48 | 50 | 50 |
| November | 50 | 50.5 | 50 | 49 | 49.2 | 49 | 41.5 | 33 | 30.5 | 26 | 24 | 26 | 29 | 33 | 37.5 | 41.5 | 44 | 50 | 49.7 | 49 | 48 | 48 | 49 | 49.5 | 50 |
| December | 50.5 | 50 | 49.7 | 49 | 49 | 50 | 51 | 42.5 | 36 | 32 | 30.7 | 31.3 | 35 | 40 | 43 | 49 | 51 | 49 | 48 | 48 | 49 | 50 | 50.5 | 50.5 | 50.5 |

Table 5.15

Propagation conditions on Murmansk-Moscow link for 10 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Murmansk-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Berlin-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 10 | |  | | | Output power | | | 0.1 kW | | SSN | | 10 | |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 16 | 15.1 | 6 | 4.2 | 8.9 | 14.4 | 12.8 | 16.5 | 18.5 | 21.8 | 24.5 | 25.2 | 25.5 | 24.5 | 23.5 | 24.5 | 7 | 14 | 14.2 | 15.5 | 16.3 | 16.7 | 16.6 | 16.6 | 16 |
| February | 15 | 17.7 | 2.5 | 4.5 | 11.5 | 12.5 | 15.1 | 15.5 | 21 | 29 | 31.3 | 31.5 | 26 | 27 | 25 | 24 | 24 | 20 | 15 | 14.5 | 15 | 15 | 16 | 16 | 15 |
| March | 7.6 | 7.2 | 7.5 | 14 | 15.5 | 12.5 | 15.5 | 16 | 23 | 25.5 | 27 | 29 | 31.5 | 30 | 26 | 23.5 | 19 | 17.5 | 20 | 17 | 14 | 13 | 13 | 10.5 | 7.6 |
| April | 15.5 | 15.5 | 15 | 15 | 14.5 | 16 | 14.3 | 16 | 25 | 31.5 | 32 | 37 | 39 | 31 | 29 | 24 | 20.5 | 16.5 | 17 | 18 | 20 | 14.7 | 13 | 14.8 | 15.5 |
| May | 17 | 18.5 | 13.5 | 13 | 9 | 12.2 | 15.5 | 21 | 31 | 29 | 29 | 33 | 34 | 39 | 29 | 22 | 20 | 17 | 16 | 16 | 16 | 17 | 18.5 | 19 | 17 |
| June | 20.5 | 18 | 14.2 | 8 | 6.5 | 11.5 | 20 | 29 | 26 | 25 | 25.5 | 25.5 | 28.5 | 31 | 32.5 | 26.5 | 20 | 17.5 | 15 | 15 | 17.2 | 17 | 17.5 | 20 | 20.5 |
| July | 16.5 | 17.5 | 15.5 | 16.7 | 14 | 16.5 | 19.5 | 27.5 | 34 | 32.5 | 32 | 33 | 36 | 40 | 30.5 | 21 | 22 | 16 | 16.5 | 16.3 | 19 | 19.5 | 21 | 17.5 | 16.5 |
| August | 16.5 | 16 | 17.5 | 15 | 16 | 18 | 17 | 22.5 | 34.5 | 33 | 33.3 | 34.5 | 38 | 31.5 | 28.5 | 24 | 19 | 16.5 | 17 | 17.5 | 20.5 | 23 | 16.5 | 16 | 17 |
| September | 9.5 | 9 | 7.9 | 16 | 13 | 16.5 | 14 | 17.5 | 24.5 | 25 | 34 | 48.5 | 31 | 32.5 | 25 | 20 | 19 | 17 | 18 | 19.5 | 18.5 | 13 | 12.5 | 11 | 9.5 |
| October | 8.5 | 6.5 | –3.5 | 13.8 | 14.5 | 15 | 13.5 | 13.5 | 18.7 | 27 | 29 | 30 | 26 | 26.5 | 24 | 20.5 | 18.5 | 18.5 | 20.5 | 18 | 14.5 | 13.5 | 13 | 12 | 8.5 |
| November | 11 | 6 | 2 | 4.8 | 13.8 | 13.5 | 16.5 | 17.3 | 16.5 | 19 | 21.3 | 26 | 26 | 25 | 22.5 | 23.5 | 20 | 13 | 12.3 | 12.5 | 13 | 13.2 | 12.5 | 15.5 | 11 |
| December | 15 | 8.5 | –0.7 | –5 | 1 | –4 | 13 | 18.5 | 23 | 24.5 | 25.3 | 26.7 | 26 | 26.5 | 24.5 | 17.5 | 7 | 5 | 6.5 | 9.5 | 13 | 15 | 15.2 | 15.2 | 15.1 |

Table 5.16

Propagation conditions on Murmansk-Moscow link for 80 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Murmansk-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 80 | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 67.7 | 66.8 | 59.3 | 59.1 | 64.4 | 64.6 | 58.7 | 51.2 | 48.8 | 45.7 | 45.4 | 48.4 | 54.3 | 57.1 | 58.1 | 60.8 | 64.7 | 66.7 | 66.2 | 65.9 | 67.7 | 67.8 | 67.9 | 67.8 | 67.7 |
| February | 67.7 | 66.8 | 63.8 | 64.3 | 66.3 | 62.7 | 51.9 | 42.4 | 41.4 | 37.5 | 37.6 | 41.3 | 45.7 | 52.9 | 54.3 | 57.5 | 59.4 | 61.9 | 66.9 | 66.7 | 67.8 | 67.9 | 67.9 | 67.9 | 67.7 |
| March | 67.4 | 67.4 | 65.5 | 66.6 | 64.9 | 52.6 | 46 | 34 | 28.7 | 24.5 | 25.3 | 30.4 | 35.3 | 40.4 | 47.5 | 51.9 | 55.6 | 55.4 | 56.9 | 59.5 | 60.7 | 62.3 | 63.4 | 67 | 67.3 |
| April | 67.8 | 67.9 | 66.6 | 63.5 | 55.7 | 46.8 | 35 | 26.6 | 19.8 | 16 | 16.2 | 21.5 | 28.2 | 33.3 | 38.4 | 48.4 | 52.7 | 55.1 | 55.5 | 56.2 | 57 | 58.5 | 59.9 | 64.6 | 67.8 |
| May | 64.5 | 64.5 | 59.5 | 54.8 | 49.3 | 33.3 | 25.6 | 16.1 | 13.2 | 10.2 | 10.1 | 14.6 | 17.9 | 23.1 | 30 | 37.8 | 49.1 | 52.4 | 55 | 56.4 | 55.6 | 56.4 | 57.1 | 61.5 | 64.5 |
| June | 59 | 58 | 55 | 43 | 34 | 25 | 15 | 10 | 8 | 6 | 5 | 6 | 9 | 13 | 16 | 27 | 34 | 45 | 49 | 52 | 56 | 56 | 56 | 59 | 59 |
| July | 61 | 62 | 60 | 56 | 43 | 34 | 23 | 16 | 12 | 10 | 11 | 13 | 16 | 21 | 27 | 35 | 45 | 49 | 52 | 54 | 55 | 55 | 56 | 59 | 61 |
| August | 66 | 67 | 67 | 62 | 55 | 41 | 32 | 21 | 16 | 14 | 15 | 19 | 26 | 30 | 33 | 45 | 49 | 51 | 53 | 53 | 55 | 56 | 59 | 63 | 66 |
| September | 67 | 67 | 66 | 65 | 58 | 47 | 34 | 26 | 24 | 15 | 22 | 29 | 33 | 38 | 42 | 51 | 55 | 56 | 56 | 57 | 58 | 59 | 62 | 67 | 67 |
| October | 67 | 67 | 65 | 66 | 64 | 52 | 46 | 37 | 34 | 31 | 32 | 38 | 43 | 50 | 51 | 54 | 57 | 56 | 56 | 58 | 58 | 60 | 61 | 67 | 67 |
| November | 67 | 67 | 65 | 65 | 66 | 59 | 52 | 48 | 44 | 41 | 41 | 46 | 52 | 55 | 55 | 57 | 58 | 60 | 64 | 64 | 63 | 63 | 63 | 67 | 67 |
| December | 68 | 68 | 65 | 65 | 65 | 64 | 59 | 54 | 56 | 53 | 53 | 55 | 58 | 60 | 58 | 60 | 63 | 67 | 67 | 67 | 68 | 68 | 68 | 68 | 68 |

Table 5.17

Propagation conditions on Warsaw-Moscow link for 80 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Warsaw-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 80 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 53 | 49 | 45 | 43 | 45 | 53 | 53 | 40 | 36 | 26 | 24 | 27 | 36 | 40 | 43 | 46 | 50 | 54 | 53 | 52 | 53 | 53 | 53 | 54 | 53 |
| February | 54 | 53 | 49 | 47 | 53 | 54 | 44 | 35 | 24 | 17 | 16 | 19 | 24 | 36 | 39 | 43 | 45 | 48 | 54 | 54 | 54 | 53 | 54 | 54 | 54 |
| March | 54 | 54 | 53 | 54 | 54 | 48 | 38 | 23 | 12 | 6 | 5 | 9 | 13 | 21 | 32 | 38 | 42 | 44 | 45 | 50 | 52 | 52 | 52 | 54 | 54 |
| April | 54 | 54 | 54 | 55 | 51 | 41 | 34 | 17 | 10 | 4 | 3 | 5 | 9 | 15 | 30 | 35 | 40 | 44 | 44 | 45 | 47 | 49 | 52 | 54 | 54 |
| May | 55 | 55 | 55 | 52 | 44 | 36 | 20 | 11 | 6 | -4 | -6 | -4 | 5 | 10 | 16 | 33 | 37 | 42 | 44 | 44 | 44 | 46 | 47 | 50 | 55 |
| June | 50 | 52 | 51 | 46 | 39 | 22 | 14 | 7 | -3 | -6 | -8 | -8 | -5 | 5 | 11 | 17 | 24 | 37 | 41 | 42 | 43 | 43 | 45 | 48 | 50 |
| July | 52 | 53 | 54 | 52 | 45 | 29 | 20 | 11 | 5 | -5 | -6 | -4 | 5 | 10 | 16 | 23 | 35 | 39 | 42 | 42 | 43 | 44 | 46 | 49 | 52 |
| August | 53 | 53 | 54 | 54 | 48 | 40 | 25 | 14 | 6 | 2 | 2 | 5 | 8 | 14 | 20 | 34 | 38 | 41 | 41 | 42 | 43 | 45 | 50 | 52 | 53 |
| September | 54 | 54 | 53 | 53 | 54 | 42 | 33 | 16 | 8 | 3 | 4 | 8 | 13 | 19 | 32 | 38 | 42 | 44 | 45 | 46 | 48 | 51 | 52 | 54 | 54 |
| October | 54 | 54 | 53 | 54 | 54 | 45 | 38 | 27 | 19 | 14 | 13 | 17 | 23 | 34 | 37 | 41 | 43 | 45 | 46 | 50 | 52 | 52 | 52 | 54 | 54 |
| November | 54 | 53 | 52 | 52 | 54 | 52 | 43 | 37 | 29 | 23 | 21 | 25 | 35 | 39 | 41 | 44 | 45 | 51 | 53 | 52 | 51 | 51 | 52 | 53 | 54 |
| December | 54 | 54 | 53 | 52 | 53 | 53 | 52 | 43 | 40 | 32 | 30 | 37 | 40 | 44 | 45 | 45 | 48 | 54 | 54 | 53 | 54 | 54 | 54 | 54 | 54 |

Table 5.18

Propagation conditions on Murmansk– Moscow link for 80 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Murmansk-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Warsaw-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 80 | |  | | | Output power | | | 0.1 kW | | SSN | | 80 | |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 14.7 | 17.8 | 14.3 | 16.1 | 19.4 | 11.6 | 5.7 | 11.2 | 12.8 | 19.7 | 21.4 | 21.4 | 18.3 | 17.1 | 15.1 | 14.8 | 14.7 | 12.7 | 13.2 | 13.9 | 14.7 | 14.8 | 14.9 | 13.8 | 14.7 |
| February | 13.7 | 13.8 | 14.8 | 17.3 | 13.3 | 8.7 | 7.9 | 7.4 | 17.4 | 20.5 | 21.6 | 22.3 | 21.7 | 16.9 | 15.3 | 14.5 | 14.4 | 13.9 | 12.9 | 12.7 | 13.8 | 14.9 | 13.9 | 13.9 | 13.7 |
| March | 13.4 | 13.4 | 12.5 | 12.6 | 10.9 | 4.6 | 8 | 11 | 16.7 | 24.5 | 25.3 | 21.4 | 22.3 | 19.4 | 15.5 | 13.9 | 13.6 | 11.4 | 11.9 | 9.5 | 8.7 | 10.3 | 11.4 | 13 | 13.3 |
| April | 13.8 | 13.9 | 12.6 | 8.5 | 4.7 | 5.8 | 1 | 9.6 | 9.8 | 16 | 16.2 | 21.5 | 19.2 | 18.3 | 8.4 | 13.4 | 12.7 | 11.1 | 11.5 | 11.2 | 10 | 9.5 | 7.9 | 10.6 | 13.8 |
| May | 9.5 | 9.5 | 4.5 | 2.8 | 5.3 | –2.7 | 5.6 | 5.1 | 13.2 | 10.2 | 10.1 | 14.6 | 17.9 | 13.1 | 14 | 4.8 | 12.1 | 10.4 | 11 | 12.4 | 11.6 | 10.4 | 10.1 | 11.5 | 9.5 |
| June | 9 | 6 | 4 | –3 | –5 | 3 | 1 | 10 | 8 | 6 | 5 | 6 | 9 | 13 | 5 | 10 | 10 | 8 | 8 | 10 | 13 | 13 | 11 | 11 | 9 |
| July | 9 | 9 | 6 | 4 | –2 | 5 | 3 | 5 | 12 | 10 | 11 | 13 | 16 | 11 | 11 | 12 | 10 | 10 | 10 | 12 | 12 | 11 | 10 | 10 | 9 |
| August | 13 | 14 | 13 | 8 | 7 | 1 | 7 | 7 | 16 | 14 | 15 | 19 | 18 | 16 | 13 | 11 | 11 | 10 | 12 | 11 | 12 | 11 | 9 | 11 | 13 |
| September | 13 | 13 | 13 | 12 | 4 | 5 | 1 | 10 | 16 | 15 | 22 | 21 | 20 | 19 | 10 | 13 | 13 | 12 | 11 | 11 | 10 | 8 | 10 | 13 | 13 |
| October | 13 | 13 | 12 | 12 | 10 | 7 | 8 | 10 | 15 | 17 | 19 | 21 | 20 | 16 | 14 | 13 | 14 | 11 | 10 | 8 | 6 | 8 | 9 | 13 | 13 |
| November | 13 | 14 | 13 | 13 | 12 | 7 | 9 | 11 | 15 | 18 | 20 | 21 | 17 | 16 | 14 | 13 | 13 | 9 | 11 | 12 | 12 | 12 | 11 | 14 | 13 |
| December | 14 | 14 | 12 | 13 | 12 | 11 | 7 | 11 | 16 | 21 | 23 | 18 | 18 | 16 | 13 | 15 | 15 | 13 | 13 | 14 | 14 | 14 | 14 | 14 | 14 |

Table 5.19

Propagation conditions on Berlin-Moscow link for 80 sunspot numbers

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interfering link: Berlin-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output power | | 0.1 kW | | SSN | | 80 | |  | | | | | | | | | | | | | | | | | |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 51 | 50 | 50 | 50 | 50 | 50 | 45 | 35 | 28 | 15 | 11 | 13 | 24 | 31 | 37 | 40 | 42 | 44 | 49 | 49 | 51 | 51 | 51 | 51 | 51 |
| February | 51 | 50 | 51 | 50 | 51 | 50 | 37 | 27 | 14 | 6 | 4 | 7 | 11 | 17 | 28 | 36 | 40 | 41 | 43 | 47 | 51 | 51 | 51 | 51 | 51 |
| March | 50 | 50 | 50 | 50 | 52 | 39 | 28 | 13 | 4 | –21 | –23 | –19 | –15 | 7 | 12 | 26 | 35 | 40 | 39 | 40 | 42 | 43 | 45 | 48 | 50 |
| April | 46 | 51 | 50 | 51 | 42 | 33 | 22 | 6 | –14 | –22 | –25 | –23 | –18 | –12 | 10 | 20 | 32 | 37 | 40 | 40 | 39 | 40 | 42 | 45 | 46 |
| May | 44 | 45 | 45 | 42 | 37 | 23 | 7 | –13 | –21 | –27 | –29 | –28 | –25 | –19 | –12 | 8 | 23 | 34 | 38 | 40 | 38 | 39 | 40 | 43 | 44 |
| June | 40 | 43 | 42 | 37 | 25 | 10 | –11 | –20 | –26 | –30 | –44 | –45 | –31 | –27 | –21 | –12 | 7 | 22 | 33 | 36 | 38 | 37 | 37 | 39 | 40 |
| July | 41 | 43 | 45 | 42 | 36 | 22 | –2 | –13 | –23 | –28 | –29 | –29 | –26 | –21 | –14 | 5 | 19 | 31 | 35 | 37 | 37 | 37 | 37 | 39 | 41 |
| August | 45 | 47 | 50 | 46 | 40 | 29 | 15 | –8 | –19 | –25 | –26 | –25 | –20 | –15 | –8 | 14 | 28 | 34 | 37 | 37 | 37 | 37 | 38 | 41 | 45 |
| September | 49 | 50 | 50 | 51 | 46 | 34 | 21 | 7 | 0 | –24 | –24 | –20 | –15 | 7 | 11 | 24 | 34 | 40 | 39 | 40 | 39 | 41 | 43 | 47 | 49 |
| October | 49 | 50 | 50 | 50 | 51 | 38 | 29 | 20 | 8 | 2 | 1 | 5 | 9 | 14 | 25 | 33 | 37 | 39 | 40 | 40 | 41 | 43 | 44 | 47 | 49 |
| November | 50 | 50 | 50 | 50 | 50 | 47 | 37 | 29 | 23 | 10 | 8 | 11 | 22 | 28 | 34 | 37 | 39 | 40 | 43 | 48 | 47 | 47 | 47 | 50 | 50 |
| December | 51 | 50 | 51 | 51 | 51 | 49 | 44 | 38 | 34 | 28 | 24 | 26 | 31 | 38 | 40 | 41 | 41 | 43 | 48 | 49 | 51 | 51 | 51 | 51 | 51 |

Table 5.20

Propagation conditions on Murmansk-Moscow link for 80 sunspot numbers with interference

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Signal/noise ratio, dB | | | | | | | | | | | | | | | | | | | | | | | | | |
| Useful link: Murmansk-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | Interfering link: Berlin-Moscow, isotropic antenna gain=0 dB | | | | | | | | | | | | | | |
| Output power | | 5 kW | | SSN | | 80 | |  | | | Output power | | | 0.1 kW | | SSN | | 10 | |  |  |  |  |  |  |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| January | 16.7 | 16.8 | 9.3 | 9.1 | 14.4 | 14.6 | 13.7 | 16.2 | 20.8 | 30.7 | 34.4 | 35.4 | 30.3 | 26.1 | 21.1 | 20.8 | 22.7 | 22.7 | 17.2 | 16.9 | 16.7 | 16.8 | 16.9 | 16.8 | 16.7 |
| February | 16.7 | 16.8 | 12.8 | 14.3 | 15.3 | 12.7 | 14.9 | 15.4 | 27.4 | 37.5 | 37.6 | 41.3 | 34.7 | 35.9 | 26.3 | 21.5 | 19.4 | 20.9 | 23.9 | 19.7 | 16.8 | 16.9 | 16.9 | 16.9 | 16.7 |
| March | 17.4 | 17.4 | 15.5 | 16.6 | 12.9 | 13.6 | 18 | 21 | 28.7 | 24.5 | 25.3 | 30.4 | 35.3 | 40.4 | 35.5 | 25.9 | 20.6 | 15.4 | 17.9 | 19.5 | 18.7 | 19.3 | 18.4 | 19 | 17.3 |
| April | 21.8 | 16.9 | 16.6 | 12.5 | 13.7 | 13.8 | 13 | 26.6 | 19.8 | 16 | 16.2 | 21.5 | 28.2 | 33.3 | 28.4 | 28.4 | 20.7 | 18.1 | 15.5 | 16.2 | 18 | 18.5 | 17.9 | 19.6 | 21.8 |
| May | 20.5 | 19.5 | 14.5 | 12.8 | 12.3 | 10.3 | 25.6 | 16.1 | 13.2 | 10.2 | 10.1 | 14.6 | 17.9 | 23.1 | 30 | 29.8 | 26.1 | 18.4 | 17 | 16.4 | 17.6 | 17.4 | 17.1 | 18.5 | 20.5 |
| June | 19 | 15 | 13 | 6 | 9 | 15 | 15 | 10 | 8 | 6 | 5 | 6 | 9 | 13 | 16 | 27 | 34 | 23 | 16 | 16 | 18 | 19 | 19 | 20 | 19 |
| July | 20 | 19 | 15 | 14 | 7 | 12 | 23 | 16 | 12 | 10 | 11 | 13 | 16 | 21 | 27 | 35 | 26 | 18 | 17 | 17 | 18 | 18 | 19 | 20 | 20 |
| August | 21 | 20 | 17 | 16 | 15 | 12 | 17 | 21 | 16 | 14 | 15 | 19 | 26 | 30 | 33 | 31 | 21 | 17 | 16 | 16 | 18 | 19 | 21 | 22 | 21 |
| September | 18 | 17 | 16 | 14 | 12 | 13 | 13 | 26 | 24 | 15 | 22 | 29 | 33 | 38 | 31 | 27 | 21 | 16 | 17 | 17 | 19 | 18 | 19 | 20 | 18 |
| October | 18 | 17 | 15 | 16 | 13 | 14 | 17 | 17 | 26 | 31 | 32 | 38 | 34 | 36 | 26 | 21 | 20 | 17 | 16 | 18 | 17 | 17 | 17 | 20 | 18 |
| November | 17 | 17 | 15 | 15 | 16 | 12 | 15 | 19 | 21 | 31 | 33 | 35 | 30 | 27 | 21 | 20 | 19 | 20 | 21 | 16 | 16 | 16 | 16 | 17 | 17 |
| December | 17 | 18 | 14 | 14 | 14 | 15 | 15 | 16 | 22 | 25 | 29 | 29 | 27 | 22 | 18 | 19 | 22 | 24 | 19 | 18 | 17 | 17 | 17 | 17 | 17 |

It is shown in Table 5.5 which contains simulation results of signal/interference ratio dependence from day time and season at low solar activity. The analysis of the simulation results showed that in case of interference time intervals when communication between Petropavlovsk-Kamchatski-Moscow is feasible are increased. For other time intervals interference can result in reduction of operation modes used by fixed communication link.

Tables 5.6-5.10 present simulation results of interference impact on operation of multihop fixed communication links at high solar activity with 80 sunspot number.

Table 5.6 presents simulation results of signal/noise ratio for Petropavlovsk-Kamchatski-Moscow fixed communication link. It is shown that increase of solar activity leads to deterioration of propagation conditions. For example in June increase of solar activity results in impossible operation of the communication link at any day time for any of the considered operation mode. In addition time interval when operation of fixed communication link is feasible is decreased in any of the considered operation mode.

Table 5.7 presents simulation results of propagation conditions on Astana-Moscow amateur radiopath. It is shown that increase of sunspot number leads to deterioration of propagation conditions for the amateur communication link.

Table 5.8 presents simulation results of signal/interference ratio for Petropavlovsk-Kamchatski-Moscow radiopath with interference caused by Astana-Moscow amateur communication link. The obtained results show that interference caused by the amateur communication link will result in blockage of data transmission almost at any daytime.

Table 5.9 presents simulation results of propagation conditions on Equator-Moscow amateur communication link.

Table 5.10 presents simulation results of signal/interference ratio for Petropavlovsk-Kamchatski-Moscow radiopath with interference caused by Equator-Moscow amateur communication link. It is shown that interference caused by the amateur communication link will result in increase of time intervals when operation of Petropavlovsk-Kamchatski-Moscow link is blocked. In other time intervals there is reduction of operation modes used by the radio link.

Tables 5.11-5.15 below present simulation results of single hop amateur communication link impact on operation of the fixed communication link with 10 sunspot numbers.

Table 5.11 contains simulation results of propagation conditions for Murmansk-Moscow fixed communication link. It is shown that without interference communication is feasible between the indicated points at all considered operation modes at any season and daytime.

Table 5.12 contains simulation results of propagation conditions for Warsaw-Moscow amateur communication link. The analysis of the obtained results shows that this amateur communication link can also operate at any season and any daytime.

Table 5.13 presents simulation results of signal/interference ratio for Murmansk-Moscow fixed communication link with interference caused by Warsaw-Moscow amateur communication link. The analysis of the results shows that interference caused by the indicated amateur communication link will result in blockage of fixed communication link operation during significant time interval. In other time intervals there is limitation of operation modes used by the fixed radio link.

Table 5.14 contains simulation results of propagation conditions Berlin-Moscow amateur communication link. The analysis of the obtained simulation results shows that this amateur communication link has interruptions of operation when the signal/noise ratio is less than 8 dB.

Table 5.15 presents simulation results of signal/interference ratio with interference caused by Berlin – Moscow amateur communication link. The analysis of the obtained simulation results shows that in spite of significant increase of distance to interference source the amateur communication link can disable fixed communication link operation at night in spring and autumn. In addition during significant time interval there can be limitations for operation modes of fixed communication link caused by interference impact.

Table 5.16 contains simulation results of propagation conditions on Murmansk-Moscow fixed communication link with 80 sunspot numbers. It is shown that increase of solar activity leads to reduction of operation mode number with high values of signal/noise ratio in morning and afternoon hours in spring, summer and winter months. In summer (in June) there is an interval when data transmission on the radio path is not feasible.

Table 5.17 contains simulation results of propagation conditions on Warsaw-Moscow amateur communication link with 80 sunspot numbers. The analysis of the obtained simulation results shows that increase of solar activity results in time intervals when data transmission on this radio path is not feasible.

Table 5.18 presents simulation results of signal/interference ratio with interference caused by Warsaw-Moscow amateur communication link at 80 sunspot number. The analysis of the obtained simulation results shows that at high solar activity amateur communication link can block fixed communication link operation at night and in the morning hours in spring, summer and autumn months. In other time there can be limitations for operation modes of fixed communication link caused by interference impact of the amateur communication link. Thus data transmission can be only in digital format except some cases.

Table 5.19 contains simulation results of propagation conditions on Berlin-Moscow amateur communication link with 80 sunspot numbers. The analysis of the obtained simulation results shows that increase of solar activity leads to extension of time intervals when data transmission is not feasible.

Table 5.20 presents simulation results of signal/interference ratio with interference caused by Berlin-Moscow amateur communication link at 80 sunspot number. The analysis of the obtained simulation results shows that interference caused by the amateur communication link results in significant reduction of time intervals when fixed communication link operation is feasible at any of three considered operation modes. Thus the link can operate only for digital voice transmission.

The analysis of the results presented in Tables 5.1-5.20 showed that:

– for the considered power value of the amateur station transmitter the protection distance required to provide interference free operation of the fixed service link can exceed 6 200 km;

– in case the distance between the amateur station transmitter and fixed link receiver is less or equal to 2 280 km then interference caused by single amateur links to fixed links using multihop mode can disable operation of fixed service links almost at any time;

– in case the distance between the amateur station transmitter and fixed link receiver is from 2 280 km up to 6 200 km then interference caused by the amateur station can disable operation of fixed service links and reduce the number of operation modes used by this link as well;

– for one-hop communication links interference from stations of the amateur service can disable the fixed links during the time intervals determined by the distance between the amateur station transmitter and the fixed link receiver, their mutual location and solar activity.

Out of these time intervals interference from stations of the amateur service can result in significant limitation of the operation mode number used by fixed communication links.

It should be noted that interference impact on operation of fixed communication links can be reduced due to usage of directional antennas in the fixed communication links. However analysis of signal/interference ratio deficit for the scenario considered above shows that it can change in wide range and can achieve 28 dB for one-hop and 41 dB for multihop fixed communication links. Such high values of signal/interference ratio deficit cannot be compensated completely by usage of directional antennas such as Yagi antenna with antenna gain from 3 dB to 8 dB in this frequency band.

Therefore compatibility between amateur stations and fixed communication links is quite complicated.

## 5.2 Compatibility of the amateur systems with the land mobile systems

[TBD]

## 5.3 Compatibility of the amateur systems with the maritime mobile systems

[TBD]

## 5.4 Compatibility of the amateur systems with the oceanographic radars

[TBD]

# 6 Conclusions

The protection distance exceeding 6 200 km can be required to provide compatibility between the amateur stations and fixed communication links. Therefore compatibility of amateur stations with the fixed service systems is quite complicated and it can require operational constraints on the amateur stations.

[TBD]]