Sharing Studies Between the Radio Astronomy Telescopes and the Power Line Communication Systems in the HF Region

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Abstract

Radio Astronomy has frequency allocations in 13.36-13.41 MHz and 25.55-25.67 MHz on a primary basis, worldwide. These bands are extensively used by radio astronomers to observe electromagnetic waves emitted by the Sun, the Jupiter and other large, gaseous planets in the solar system. The powers from a single PLC system in the above radio astronomy bands are –33 dBW and -29.2 dBW, respectively, and therefore the PLC systems seem to be a harmful interference source for the radio astronomical observation in the HF band. It is necessary to keep an adequate separation distance to avoid harmful interference to the radio astronomy telescope, and we calculated the separation distance based on the free-propagation method. We obtained a value of 424 km. If the PLC system is widely deployed, it is sure that the interference level increase greatly and the separation distance will become much larger. Thus it was recognized that it is quite difficult to share frequencies with the PLC systems and radio astronomy telescopes, at least, in Japan, and that a new technology to dramatically reduce leaked emissions from the power lines are crucial for the PLC systems to coexist with other radiocommunication services.

1. Introduction

Radio Astronomy has been recognized as a radiocommunication service, the Radio Astronomy Service (RAS), in the International Telecommunication Union (ITU), and it has frequency allocations in 13.36-13.41 MHz and 25.55-25.67 MHz (hereafter, HF) on a primary basis. These bands are extensively used by radio astronomers to observe electromagnetic waves emitted by the Sun, the Jupiter and other large, gaseous planets in the solar system. The emission from the Sun is mainly produced through the synchrotron emission due to accelerated electrons nearly to the speed of light, and is distributed continuously across wide range of frequency – these are called as the continuum emissions. The emission mechanism from the Jupiter is not well known, but it is believed that the interaction between magnetic fields and electrons in the polar regions – the auroral regions – play a quite important roll for the HF emissions.

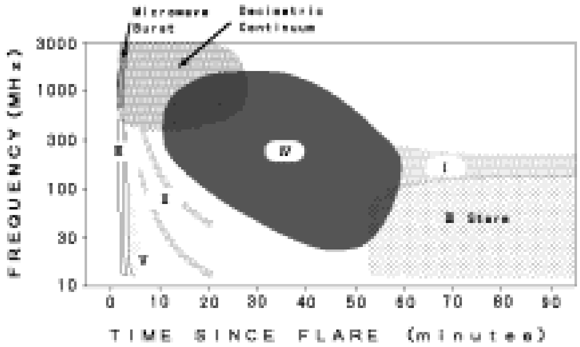

Figure 1. Burst types from the Sun

Figure 1[1] shows classification of radio bursts from the Sun. It is clearly seen in this figure that the emission is distributed from 10 MHz up to 3 000 MHz. In the HF region all burst types except for II are observed. Especially the type III Storm is mainly observed in the HF region for long duration. Strong solar bursts sometimes interrupt radio communications on the Earth. The HF band is used, for example, by aircrafts to communicate with control towers in remote airports. Thus it is crucial to monitor solar bursts to predict possible interference to such important radio communications, and, the Communication Research Laboratory of Japan has started the “solar weather forecast” for many years.

In this paper we report the results of frequency sharing between the HF radio astronomy observations and one of proposed PLC system in Japan to investigate if it is possible for the both systems to coexist.

2. Sharing Studies between the Radio Astronomy Service and the PLC System in the HF Region

2.1. Protection criteria of the RAS in the HF region

The protection criteria is defined in Recommendation ITU-R RA.769[2]. Table 1 of the recommendation gives the criteria for the continuum observations, and the values, as the input interference power, are –185 dBW for the 13.36-13.41 MHz band and –188 dBW for the 25.55-25.67 MHz band, respectively.

As is described in detail in Recommendation ITU-R RA.769, these values represent protection criteria for "typical" observations; it assumes an integration (observations) time of 2 000 seconds and an antenna gain of 0 dBi. Actual radio astronomy antenna does not have the ***static*** antenna gain of 0 dBi. Recommendation ITU-R SA.509[3] provides the antenna gain pattern of the radio astronomy antenna (see, Figure 2).

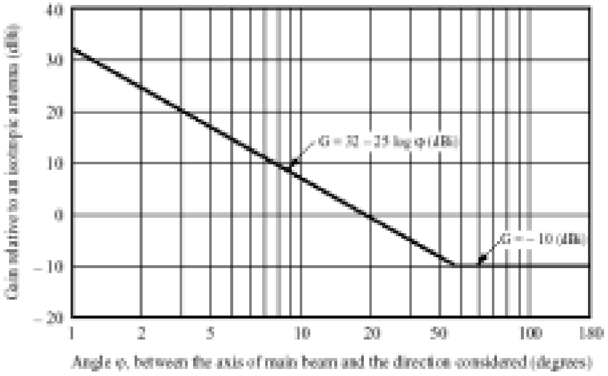

Figure 2. RAS Antenna Pattern given in Rec. ITU-R. SA.509

If we recall the fact that radio astronomy antennas have to track the target objects on the sky, it is easy to understand that relative angle between a radio astronomy antenna and an interferer varies as a function of time. Thus the antenna gain ***averaged over the upper hemisphere*** should be used in the assessment of interference, and the averaged value, by using the antenna pattern given in Recommendation ITU-R SA.509, is around 3 dBi. For simplicity the value of 0 dBi is used in the ITU.

2.2. The PLC system used for the study

High Frequency Power line communication (PLC) system using the frequency band between 2 to 30 MHz has been proposed in Japan. The proposed system requires high power transmission (-50 dBm/Hz) because a power line is not designed as a communication line, and consequently the power lines emit substantial electromagnetic waves in the HF band. Figure 3 shows the power spectrum of the Home Plug Network of the US. It should be noted that Japanese proposed PLC system has not publicized the power spectrum distribution. Figure 3 gives locations of the HF RAS bands for comparison.

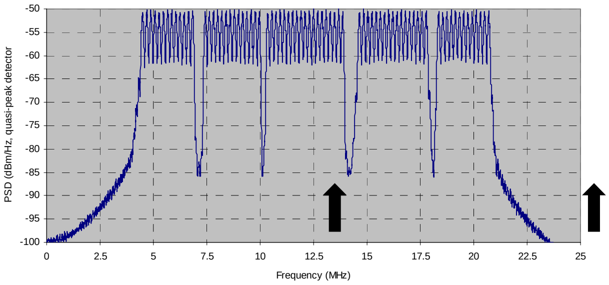

Figure 3. Power Spectrum Distribution of a PLC System and the HF RAS Bands

We adopted the antenna gain of power line of –20 dBi based on measurements by Muto *et al*[4].

2.3. Calculations

2.3.1. Equation to calculate received power by a RAS antenna

The received power by a radio astronomy antenna is calculated by

$$Pr = Pt - L_{bf} + Gr , \qquad (1)$$

where

Pr : the received power by the radio astronomy antenna (dBW)

Pt : transmitted power at a distance of 30 m from the transmitter (dBW)

Gr : antenna gain of the radio astronomy antenna toward the transmitter (dBi)

L_{bf} : propagation loss beyond 30m from the transmitter (dB)

Given the radio astronomy antenna gain (0 dBi) and gain of power line (-20 dBi), it is necessary to evaluate Pt and L_{bf} before calculating the received power by the radio astronomy antenna.

It should be noted that we do not have to evaluate the received power based on transmitted power at 30m. However the regulatory provisions in the FCC is defined at a distance of 30 m, and this method would provide a simple conversion formula.

2.3.2. Calculations of transmitted power at a distance of 30 m from the transmitter

It is possible to calculate the transmitted field strength at a distance of 30 m, *E*, from a transmitter by using equation

(1) in section 2 of Recommendation ITU-R PN. 525[5] as follows:

$$E = \mathrm{sqrt}(30\ Gt\ P) / d \qquad (2)$$

$$= \mathrm{sqrt}[30 \times 10^{-2} \times (13410000-13360000) \times 0.00000001] / 30$$

$$= 408\ [\mu V/m]\ (@13MHz\ band)$$

and

$$E = \mathrm{sqrt}[30 \times 10^{-2} \times (25670000-25550000) \times 0.00000001] / 30$$

$$= 633\ [\mu V/m]\ (@25MHz\ band)$$

Then the field strength is converted into power by using equation (8) in section 4 of Recommendation ITU-R PN.525,

$$Pr = E - 20\log f - 167.2 \qquad (3)$$

where Pr (dBW), E (dB(μV/m)) and f (GHz)=13.385 / 1000 and 25.610 / 1000.

Therefore the received power by a radio astronomy antenna with the gain of 0 dBi is given as,

$$Pr = E - 20\log f - 167.2$$

$$= 20 \log 408 - 20 \log (13.385 /1000) - 167.2$$

$$= - 77.52\ dBW \quad (@13MHz\ band),$$

and

$$= 20 \log 633 - 20 \log (25.610/1000) - 167.2$$

$$= - 79.34\ dBW \quad (@25MHz\ band).$$

These values are far above the protection criteria of the RAS receivers. Therefore it is necessary to reduce the received power by establishing very long separation distance between the RAS antenna and the PLC system.

2.3.3. Propagation loss beyond 30m from the transmitter

We adopted the free-space propagation model to evaluate propagation loss between the RAS antenna and the PLC system, based on Recommendation ITU-R PN. 525[5]. This model does not include the effect due to atmospheric attenuation. The atmospheric attenuation is only 2.5 x 10^{-2} dB/km (Figure 1 of Recommendation ITU-R P.676[6]), therefore we neglected the attenuation.
The free-space propagation loss between isotropic antennas, L_{bf} (dB), is given in equation (4) in section 2.2 of Recommendation ITU-R PN. 525[5] as follows:

$$L_{bf} = 32.4 + 20 \log f + 20 \log d, \qquad (4)$$

where f is the frequency in MHz, and d is the distance between the RAS antenna and the PLC system in km.

2.3.4 Calculations of separation distances

As was stated in 2.3.2 the received powers are much higher than the interference criteria harmful to the radio astronomy antennas, -185 dBW (13MHz) and –188 dBW (25MHz). Now we can calculate the separation distance, d, by combining results in sections 2.3.2 and 2.3.4.

At the 13 MHz band,

$$L_{bf} = -77.52 - (-185) = 107.48\ (dB)$$

$$32.4 + 20 \log (13.385) + 20 \log d = 107.48$$

$$d = 424\ (km)\ .$$

And at the 25 MHz band,

$$L_{bf} = -79.34 - (-185) = 108.66\ (dB)$$

$$32.4 + 20 \log (25.610) + 20 \log d = 108.66$$

$$d = 253\ (km).$$

Since the PLC system plans to use the band 2-30 MHz, it is necessary to have the separation distance of 424 km to protect the HF radio astronomy antenna from interference caused by a ***SINGLE*** PLC system.

Table 1. List of the HF RAS sites in Japan

Site	longitude	latitude	Frequency (MHz)
Kochi	133E31'	33N33'	20 - 35
Nishi-Harima	134E20'	35N01'	18 - 60
Zao*	140E32'	38N06'	20 - 40
Hiraiso	140E38'	36N22'	25 - 80

note: the Zao site consists of four antennas deployed in an area with diameter of a few 10s km.

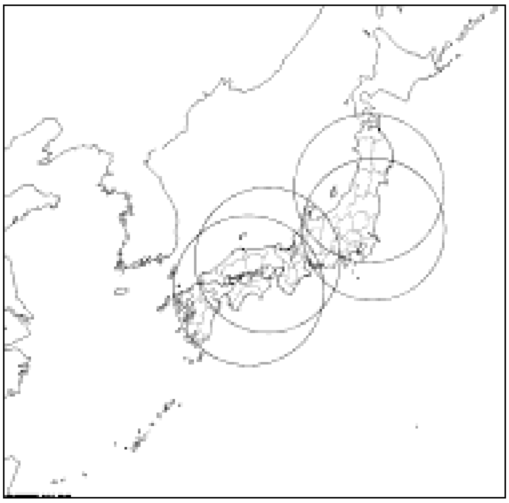

Figure 4. Distribution of Circles of radius of about 400 km around HF RAS stations in Japan

3. Discussion

3.1. Possible areas where the PLC systems could be deployed without causing harmful interference to the RAS in Japan

Table 1 lists radio astronomy antennas operating in the HF region in Japan. And Figure 4 shows an illustration to give an idea where the PLC systems could be deployed. It is clearly seen that most of Japan are excluded for the PLC system from the point of view that the system should not cause harmful interference to the RAS antennas. The only areas where the PLC systems could operate are the Hokkaido and the Okinawa.

3.2. Consideration on multiple PLC systems

It is clear that the PLC system consists of multiple modems to communicate. Thus it is necessary to consider the case when there are enough number of the PLC modems. The ADSL system has been introduced, and more than 1 000 000 systems were already used in Japan nationwide. Therefore we assume that 10 000 PLC modems are deployed in an area, because there are more than 100 major cities in Japan. In this case the aggregate transmitted power from the PLC system becomes 10 000 (= 40 dB) higher than the case for a single system, and necessary separation distance to protect the RAS antenna becomes 20 dB larger, i.e., the distance is larger than the radius of the Earth. And because there could be more than 100 such a system in Japan, it is concluded that the HF RAS are never protected in Japan.

3.3. The case that the diffraction propagation

We considered a very simple propagation model – the free-propagation – above. Some radio astronomy antenna is located in a remote mountain area to avoid any interference. In such a case it is not appropriate to adopt the free-propagation model, and diffraction-propagation should be taken into account.

Recommendation ITU-R P.526[7] provides a guidance for the diffraction propagation model, and its Annex provides nomograms to get propagation loss due to diffraction relative to the free-propagation case. For example, Figure 2 gives diffraction by a spherical earth – effect of distance. The figure gives us that diffraction-propagation loss is larger for distance of 38 km (@25 MHz and k=1, where k is the effective Earth radius factor, defined in Recommendation ITU-R P.310[8]), and that additional loss of about 20 dB is obtained for a distance of 100 km. However these nomograms also suggest that diffraction does not give very large additional loss if the separation distance is not so large. Such an additional loss would be, unfortunately, offset when a large number of PLC systems were deployed.

It should be noted that the Hiraiso telescope is located at the edge of the Kanto plains, and we can not apply the diffraction model for this case.

3.4. Reduction of leaked emission from the PLC system

It was found that the proposed PLC system is so difficult to be deployed in Japan. However if a new technique to reduce transmitted power as the electro-magnetic wave was dramatically reduced, it would be possible for the PLC system to operate in Japan. For example, if the leaked emission is reduced by 60 dB, the separation distance between the HF RAS antenna and the PLC system becomes about 0.4 km which is lowered by 30 dB than the case for currently proposed PLC system. In such a case it would be possible to deploy 10 000 PLC modems by establishing an exclusion zone of a radius of 40 km around each RAS telescope. If the degree of reduction is less than 60 dB, the radius of the exclusion zone becomes larger accordingly.

4. Conclusions

It was found necessary to keep an adequate separation distance between a PLC system and a RAS antenna to avoid harmful interference to the radio astronomy telescope. We calculated the separation distance based on the free-propagation method, and the value was 424 km. If the PLC system is widely deployed, it is sure that the interference level increase greatly and the separation distance will become much larger. Thus it was recognized that it is quite difficult to share frequencies with the PLC systems and radio astronomy telescopes, at least, in Japan, and that a new technology to dramatically reduce leaked emissions from the power lines are crucial for the PLC systems to coexist with other radiocommunication services.

It would be required in future to develop more practical model to access interference cause by the PLC system.

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