RECOMMENDATION ITU-R RS.1749

Mitigation technique to facilitate the use of the 1 215-1 300 MHz band by the Earth exploration-satellite service (active) and the space research service (active)

(Question ITU-R 234/7)

(2006)

Scope

This Recommendation describes the mitigation technique of using filtering with Fourier transformation of the received signal. This technique applies to interference to synthetic aperture radars (SARs) in the 1 215-1 300 MHz band from other services with relatively small bandwidth. This Recommendation also provides typical parameters for spaceborne active sensors to be used in the development of additional mitigation techniques.

The ITU Radiocommunication Assembly,

considering

a) that the 1 215-1 300 MHz band is allocated on a primary basis to the Earth exploration-satellite service (active);

b) that this band is used by spaceborne synthetic aperture radars (SARs) which applications are to monitor, under all-weather and day and night conditions, deformation of the Earth's surface in most land areas, natural disasters, the environment, forests, land use, and others;

c) that the 1 215-1 300 MHz band is also allocated to the radiolocation service on a primary basis, and to the radionavigation service on a primary basis in a certain number of countries;

d) that Recommendations ITU-R SA.516 and ITU-R SA.1282 show that the operation of SARs is possible without harmful interference in the same frequency band as systems operating in the radiolocation service, including wind profiler radars, with the possible exception of radio-location service systems using frequency-modulated pulsed radars;

e) that performance and interference criteria of spaceborne active sensors are given in Recommendation ITU-R SA.1166;

f) that air route surveillance radars (ARSRs) with higher isotropically radiated powers than the main beam powers of wind profiler radars have been in operation in this band for many years and harmful interference to spaceborne active sensor operations is normally not observed, although degraded performance is sometimes observed which may be attributed to ARSR transmissions,

recommends

1 that a mitigation technique applicable to the spaceborne active sensors as shown in Annex 1 could be used to reduce interference from radiolocation and radionavigation radar systems operating in the 1 215-1 300 MHz band to these sensors;

2 that typical parameters of spaceborne active sensors operating in the 1 215-1 300 MHz band given in Annex 2 should be used in the development of additional mitigation techniques.

Annex 1

Mitigation technique for interference to spaceborne SARs

1 Introduction

At some locations on Earth, bright lines appear in the images of the L-band Synthetic Aperture Radar/Japanese Earth Resources Satellite-1 (L-SAR/JERS-1). These bright lines are due to harmful radio frequency interference (RFI) from terrestrial radars. It has been shown that it is possible to eliminate the interference that causes these bright lines by conducting frequency analysis of the input data. The use of this technique will make it possible to resolve the current problem of RFI to SARs operating in the 1 215-1 300 MHz band.

2 Method and results

2.1 Method

The power level of the interfering signal is larger than that of the desired signal of the SAR as the interfering signal is a direct emission from the transmitter of terrestrial radars. So, when a Fourier transformation on the received signal is performed, the interfering wave components appear as spikes on the frequency axis. Focusing on these characteristics, as a pre-processing operation of range compression, we compare the power of each frequency "bin" with both the power spectra taken by Fourier transformation from the received signal and the original SAR signal (assuming that each component's total power is equal to the desired component of the received signal) and 0 is adopted for the power of the specified frequency "bins" that have more power than expected (hereinafter referred to as "filtering").

Furthermore, considering that the interference components that are not correlated with the SAR signal are suppressed by about 30 dB through range compression, and to prevent original signal loss, a 3 dB or more difference is adopted as the criterion between the desired signal and the interference in this case. When processed using longer time units, there is a tendency for spiked frequencies to scatter widely among the frequency spectrum and occasionally to result in the loss of the desired signal. For this reason, the received signal is divided into appropriate segments and then processed by methods such as Fourier transformation. (In this process, 1 024 azimuth lines are regarded as 1 segment.)

2.2 Interference suppression process

Specific procedures for the interference suppression process are as follows:

Step 1 : Divide received signal, including interference, into small segments

Signal of segment: S_r = received signal including interference, f_r = SAR reference signal (power adjusted with S_r)

Step 2 : Apply Fourier transformation to each segment

Transformed spectrum: $F(S_r)$, $F(f_r)$

Step 3 : Compare power in each frequency bin

Compare $|F(S_r)|$ to $|F(f_r)|$

Step 4 : Identify frequency bins containing interference

$$I = |F(S_r)| - |F(f_r)| \geq 3 \text{ dB}$$

Step 5 : Generate filter

Filter: $A(\omega)$: $I \geq 3$ dB $\rightarrow A(\omega) = 0$, $I < 3$ dB $\rightarrow A(\omega) = 1$

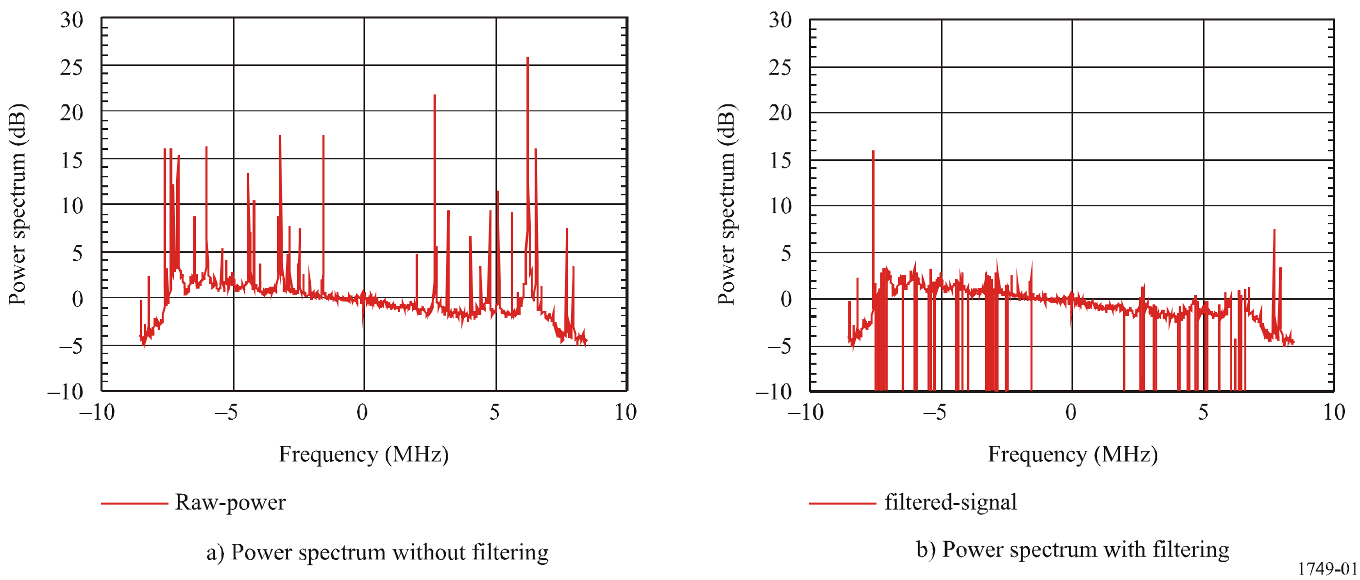
Step 6 : Apply range compression

$$Sc = F^{-1} [\{F(S_r) \times A(\omega)\} \times F(f_r)]$$

Figure 1 shows an example of the power spectrum before and after filtering using the above-mentioned process.

FIGURE 1

Power spectrum of received SAR signal with and without filtering



a) Power spectrum without filtering

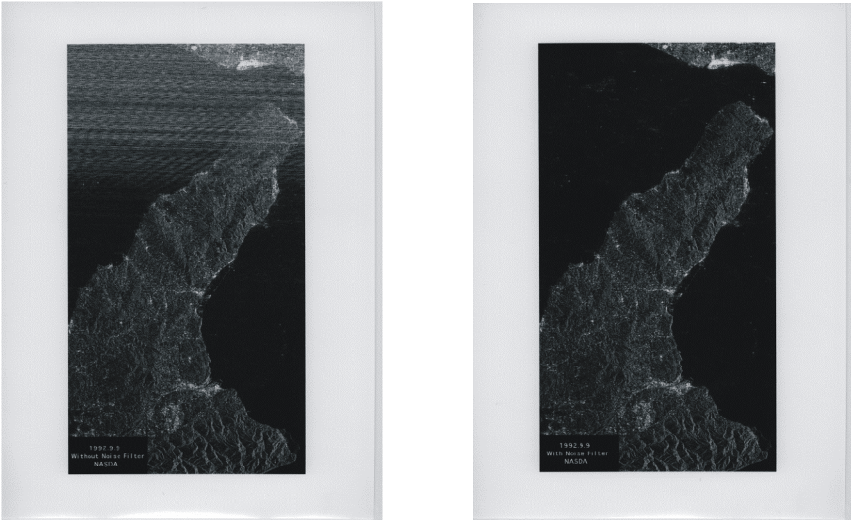
b) Power spectrum with filtering

2.3 Results

Figure 2 shows the output image with and without filtering of the received signal at the point (Awaji island near Kobe city in Japan) where the harmful interference represented by bright lines is extremely large. It is evident from this example of the corrected SAR image that it is possible to almost completely eliminate RFI due to terrestrial radar. No significant damage to the image is results from this process. The range as estimated from this analysis result is, however, in terms of probability, no more than the interference from existing terrestrial radars (including ARSR), where only one interference source can be taken into account. If more than one interference source is present in the future, distortion of the output signal caused by the reduction of the original signals through filtering of various frequencies must also be considered. In the case that the number of instances of interference increases, further study of such interference mitigation techniques will be necessary. Also, in the case of wideband RFI, such that a significant portion of the SAR bandwidth is affected, further study of such interference mitigation techniques will be necessary.

FIGURE 2

SAR imagery with and without filtering



a) SAR imagery without filtering　　b) SAR imagery with filtering

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3 Conclusion

As a result of the introduction of this filtering procedure to eliminate interference noise, it has been shown that it is possible for SAR users to filter out certain narrow-band RFI to SARs operating in the 1 215-1 300 MHz band. This narrow-band RFI represents only a few frequency bins within the SAR bandwidth.

Filtering out of wideband RFI from radars such as frequency-modulated pulsed ground-based radars, however, is more difficult due to their wide band nature. This wideband RFI can represent a significant portion of the SAR bandwidth, whereas much of the SAR signal is also eliminated along with the RFI.

Annex 2

Technical characteristics of spaceborne active sensors in the 1 215-1 300 MHz band

Technical characteristics of spaceborne active sensors in the 1 215-1 300 MHz band are given in Table 1.

TABLE 1

Parameter	SAR 1	SAR 2	SAR 3	SAR 4	SAR 5
Orbital altitude (km)	600	690	570	675	606
Orbital inclination (degrees)	97.5	98	98	98	97.8
RF centre frequency (MHz)	1 257.5	1 270	1 275	1 258	1 257.5
Peak radiated power (W)	8 000	2 000	1 200	14 000	1 000
Polarization	Horizontal/ Vertical	HH/VV	HH	H/V	HH/VV/ HV/VH
Pulse modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp
Pulse bandwidth (MHz)	3-80	30	15	55	85
Pulse duration (μs)	3-15	20-40	35	40	10-20
Pulse repetition rate (pps)	1 400-1 700	1 500-4 000	1 500-1 600	2 000	2 660-2 718
Duty cycle (%)	5.5	5.5	5.5	<10	5.5
Range compression ratio	12-1 200	280-1 120	525	2 200	850-1 700
Antenna type	Phased array	Phased array	Array	Phased array	Reflector
Antenna peak gain	37.0 dBi	36.0 dBi	33.5 dBi	37.5 dBi	35.5 dB
Antenna orientation (degrees)	20 to 50 from Nadir	10 to 51 from Nadir	35 from Nadir	13.6 to 51.8 from Nadir	20°-45 from Nadir
Antenna beamwidth (degrees)	4.3 (El) 1.1 (Az)	3.42 (El) 1.35 (Az)	5.6 (El) 1.05 (Az)	4.84 (El) 1.14 (Az)	3.1 (El) 2.0 (Az)
Antenna polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal	Linear horizontal/ vertical	Linear horizontal/ vertical
System noise temperature (K)	800	600	600	600	600
Operating time (%)	30 orbit	50 orbit	30 orbit	30 orbit	15 orbit
Minimum time for imaging (s)	3-130	10-50	11	4-67	2-8
Service area	Land masses and coastal area	Land masses and coastal area	Land masses and coastal areas	Land masses and coastal areas	Land masses and coastal area
Image swath width (km)	20/900	70/350	75	30 to >200	15/60