MEASUREMENTS AND CHARACTERISTICS OF RFI FOR A LOW-BANDWIDTH VHF SAR SYSTEM

R.T. Lord, M.R. Inggs

Radar Remote Sensing Group, Dept. EE, University of Cape Town
Private Bag, Rondebosch 7701, South Africa
Tel: +27 21 650 3756, Fax: +27 21 650 3465, E-mail: rlord@rrsg.ee.uct.ac.za

ABSTRACT

Radio frequency interference (RFI) is a major problem for low-frequency (VHF/UHF) SAR systems. Images obtained from the VHF-band *South African SAR* (SASAR) system have shown that even in remote areas in South Africa the VHF-band is heavily contaminated with RFI. This paper presents an initial investigation into the RFI environment encountered in South Africa in the VHF-band by analysing RFI that has been recorded by the SASAR system. This investigation includes RFI characteristics such as the identity (type) of the interference emitters, the number and density of emitters, their effective radiated power and their bandwidths. The results of cleaning an RFI-contaminated SASAR image with an LMS adaptive filter are also presented.

1 INTRODUCTION

VHF sensors offer unique opportunities for foliage and ground penetration applications. Unfortunately the VHF/UHF portion of the spectrum is already in heavy use by other services, such as television, mobile communications, radio and cellular phones. Even in remote locations the interference power often exceeds receiver noise by many dB, becoming the limiting factor on system sensitivity and severely degrading the image quality. RFI suppression is therefore an important aspect of low-frequency SAR systems.

The most direct way to measure RFI is to make use of "sniffer" pulses or "listening beforehand" schemes [1]. A similar method entails the recording of data before the transmitted pulse has returned to the receiver, i.e. before the nadir return. Both of these methods were employed by the SASAR system and therefore offer the unique opportunity to measure and characterise the RFI environment at VHF-band in South Africa.

Modelling the interference environment includes information such as:

- Identity (type) of emitters;
- The number and density of emitters;
- Their effective radiated power;
- Their bandwidths.

These characteristics are investigated in Section 3. Results obtained from cleaning an RFI contaminated SASAR image are shown in Section 4.

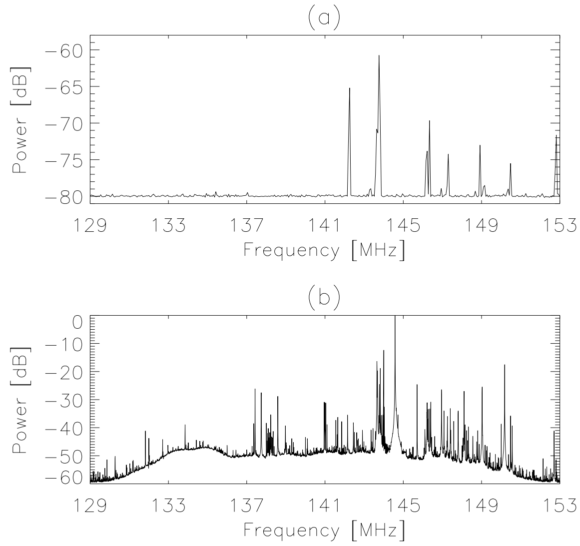

Figure 1: *(a) RFI measured in Cape Town with a spectrum analyser; (b) RFI measured with the SASAR system near the Southern Cape, South Africa.*

2 RFI MEASUREMENTS

In order to assess the amount of RFI that could be expected by the SASAR system in the Cape Town area, a simple quarter wavelength antenna was attached to a spectrum analyser with a bandwidth resolution of 10 kHz. The output of the spectrum analyser from 129–153 MHz is shown in Figure 1 (a). This figure shows that there is significant RFI just above 141 MHz, which is the centre frequency of the SASAR system.

During a recent flight over the Southern Cape area in South Africa, the blanking switch of the SASAR system was deliberately switched on, so that no pulses were transmitted. This permitted the background interference to be recorded. Since the sampling rate of the SASAR system is 24 MHz, the recorded spectrum ranges from 129 MHz to 153 MHz, centred around 141 MHz. Figure 1 (b) shows the magnitude averaged range spectrum of 1000 range lines for the H-receive polarisation data, with a PRF of 136 Hz. The averaging of magnitude range spectra is performed in order to enhance the interference which is often fairly constant, whereas the noise, due to its random nature, averages

Frequency Band (MHz)	*Main Allocations*
87.5–108	FM Sound Broadcasting
108–137	Aeronautical Radionavigation / Aeronautical Mobile
137–138	Mobile-Satellite / Meteorological-Satellite / Mobile / Space Operation & Research
138–144	Mobile / Fixed
144–146	Amateur / Amateur-Satellite
146–148	Mobile / Fixed
148–149.9	Mobile-Satellite (Earth-to-Space) / Mobile / Fixed
149.9–150.05	Radionavigation-Satellite / Land Mobile-Satellite
150.05–174	Mobile / Fixed / Maritime Mobile

Table I: *Radio spectrum allocation plan in South Africa: 87.5–174 MHz.*

out. Note that this graph shows that the antenna and receive filters have not adequately limited the receive bandwidth to 12 MHz, which is the transmitted pulse bandwidth of this system.

Although not shown, the dominant interference for V-receive polarisation was found to be about 5 dB less than for H-receive polarisation. Even though the interference pattern shown in Figure 1 (b) is not identical to the pattern measured by the spectrum analyser, the dominant interference in this case is again situated above 141 MHz.

3 RFI CHARACTERISTICS

3.1 IDENTITY OF EMITTERS

The information presented here regarding the identity of emitters has been obtained from a document produced by the *Department of Posts and Telecommunications* (DPT) in South Africa in 1996, with the assistance of Smith System Engineering and the CSIR, as part of Project SABRE (*South African Band Replanning Exercise*) [3]. This document details the frequency allocation plan for the future use of the radio spectrum in South Africa between the frequencies 20 MHz and 3 GHz. The VHF/UHF spectrum in South Africa is already utilised by a wide range of systems and services, such as:

- Telephone services to rural areas and disadvantaged communities;
- Television and radio broadcasts;
- Mobile radio systems used by commercial organisations;
- Emergency communications by the police, fire and ambulance services, etc.;
- Cellular, cordless telephones and pagers;
- Satellites (for telecommunication and broadcasting);
- Alarm systems, remote control devices, etc.

Table I presents the radio spectrum allocation plan in South Africa between 87.5 MHz and 174 MHz. Only the main allocations are summarised, in order to present an overview of the spectrum allocation. More detailed information can be obtained from the SABRE document [3].

3.2 NUMBER AND DENSITY OF EMITTERS

In order to count the number of RFI spikes shown in Figure 1 (b), the noise floor was estimated and subtracted from this graph. This can be achieved by applying a median filter to the averaged range spectrum. Median filtering is effective in removing isolated high or low values, which in this application are the RFI spikes.

Figure 2 shows the number of RFI spikes for both H- and V-receive polarisations as a function of power above the noise floor. Most RFI spikes are less than 10 dB above the noise floor. Only about 10 emitters where counted to be above 20 dB of the noise floor. It is important to note, however, that many emitters are so closely spaced that they appear to be single emitters with larger bandwidths. Referring to Figure 1 (b) there appear to be many emitters lumped together just below 145 MHz and in the region from 146–150 MHz. The next subsection investigates the bandwidth of the emitters with respect to their power level above the noise floor.

3.3 RADIATED POWER AND BANDWIDTH

Surveys performed by the Grumman E-2C UHF radar (420–450 MHz) [6] have shown that 50 % of emitters have a spectral bandwidth between 0–50 kHz

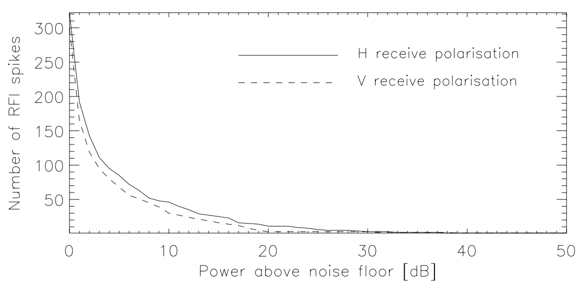

Figure 2: *Number of RFI spikes for both H and V polarisation versus power above noise floor.*

Cutoff (*dB*)	*% Emitters with bandwidths (in kHz)*			
	0–10	11–20	21–50	> 50
2	62	19	10	9
3	62	18	12	8
5	58	18	16	8
10	62	24	9	5
20	71	21	1	7

Table II: *Percentage of RFI emitters within specified frequency bands and above specified power level above noise floor*

(single channel voice/radio telegraphy), 40 % between 50–150 kHz and less than 10 % have a bandwidth greater than 150 kHz (data communications, multi-channel telephony, etc.) It is important to estimate the modulation time of the RFI, which is the inverse of the RFI bandwidth, in order to predict whether the parameters of the modelled sinusoidal interference change across one range line, so as to deduce whether the model of the RFI consisting of sinusoidal tones breaks down. According to Braunstein *et al* [2], most RFI has a modulation time of 5–10 μs, which is consistent with an effective bandwidth of a few hundred kHz or less.

The graph shown in Figure 1 (b) has been investigated to find the percentage of RFI emitters that have a specified bandwidth and a specified power level above the noise floor. The results of this investigation are listed in Table II. For example 58 % of emitters which are above 5 dB of the noise floor have a bandwidth between 0 and 10 kHz. Less than 10 % of emitters have a bandwidth greater than 50 kHz, regardless of their power level above the noise floor. These findings suggest that for this isolated case the RFI environment is more narrowband than that encountered by the Grumman E-2C UHF radar, since about 60 % of emitters investigated have a bandwidth less than 10 kHz. This also suggests that RFI suppression algorithms that model the RFI as sinusoidal tones, such as the LMS adaptive filter, are applicable under these circumstances.

4 RFI SUPPRESSION RESULTS

The VHF-band image displayed in Figure 3 was generated by the SASAR system and shows an area in the vicinity of Upington, South Africa. The raw data was processed with the G2 range-Doppler processor developed at the University of Cape Town. The size of the image is 16.7 km in azimuth and 12.8 km in range. The RFI in this image is very severe, hiding many features which become visible only once the interference has been suppressed.

This image has been cleaned with an LMS adaptive filter, which is widely used in interference suppression applications [1], [5], [7], [9], [10]. In contrast to fixed filters, they have the desirable property of being able to adjust their own parameters automatically. Little or no *a priori* knowledge of the signal or noise characteristics is required. It is, however, assumed that the interference is sinusoidal. This assumption is reasonable if one expects 60 % of RFI emitters to have a bandwidth less than 10 kHz.

Figure 3 displays the VHF-band image after it has been cleaned with a 256-tap LMS adaptive filter. The cleaned image is a vast improvement when compared to the noisy image. Many faint features have become visible, especially in the right half of the image.

5 CONCLUSIONS

This paper has demonstrated the results of an initial study into the RFI environment encountered by the SASAR system in South Africa. The SASAR system has recorded data with the blanking switch deliberately switched on, so that no pulses were transmitted. This permitted the background interference to be recorded and investigated. RFI characteristics such as the identity (type) of the interference emitters, the number and density of emitters, their effective radiated power and their bandwidths were discussed. It was found that about 60 % of RFI emitters investigated have a bandwidth less than 10 kHz, which validates the application of RFI suppression algorithms that model the RFI as sinusoidal tones, such as the LMS adaptive filter. A VHF-band image generated by the SASAR system, which was heavily contaminated with RFI, was subsequently cleaned with an LMS adaptive filter. Many faint features of the image became visible after RFI suppression.

6 REFERENCES

[1] K. Abend and J. McCorkle, “Radio and TV interference extraction for ultra-wideband radar,” in *Algorithms for Synthetic Aperture Radar Imagery II* (D.A. Giglio, ed.), SPIE, Orlando, FL, vol. 2487, pp. 119–129, April 1995.

[2] M. Braunstein, J. Ralston and D. Sparrow, “Signal processing approaches to radio frequency interference (RFI) suppression,” in *Algorithms for Synthetic Aperture Radar Imagery* (D.A. Giglio, ed.), SPIE, Orlando, FL, vol. 2230, pp. 190–208, April 1994.

[3] DPT, “Project SABRE (South African Band Replanning Exercise) - Band Plan for the Frequencies 20/,MHz to 3/,GHz”, Department of Posts and Telecommunications, October, 1996.

[4] B.H. Ferrell, “Interference Suppression in UHF Synthetic-Aperture Radar,” in *Algorithms for Synthetic Aperture Radar Imagery II* (D.A. Giglio, ed.), SPIE, Orlando, FL, vol. 2487, pp. 96–106, April 1995.

[5] J.R. Glover, Jr., “Adaptive Noise Cancelling Applied to Sinusoidal Interferences,” *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-25, no. 6, pp. 484–491, December 1977.

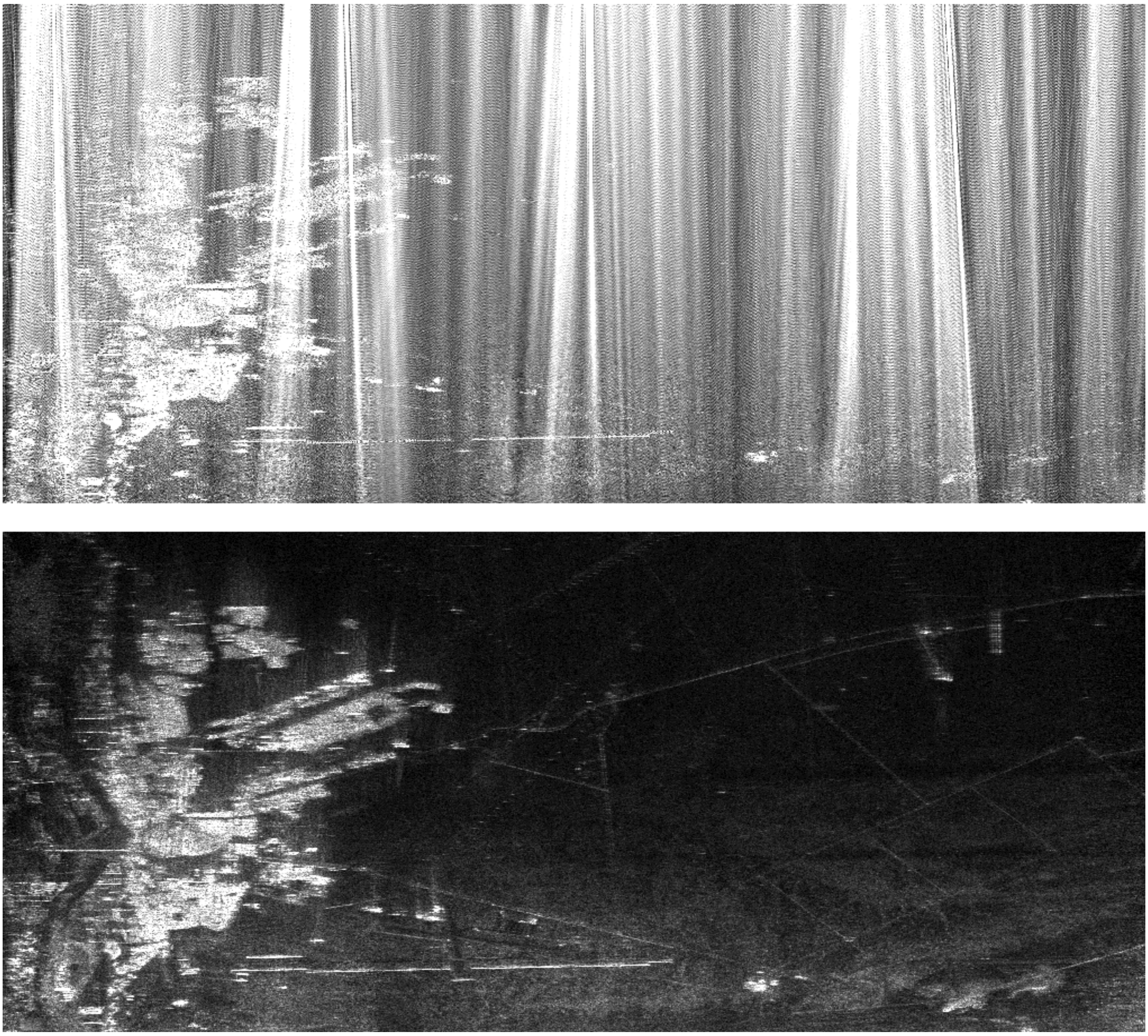

Figure 3: *SASAR VHF-band image of the vicinity of Upington, South Africa, contaminated with RFI (top) and cleaned with LMS adaptive filter (bottom). The flight path is along the horizontal axis, with near range towards the bottom of the image.*

[6] T. Koutsoudis and L. Lovas, "RF Interference Suppression in Ultra Wideband Radar Receivers," in *Algorithms for Synthetic Aperture Radar Imagery II* (D.A. Giglio, ed.), SPIE, Orlando, FL, vol. 2487, pp. 107–118, April 1995.

[7] C.T.C. Le, S. Hensley and E. Chapin, "Removal of RFI in Wideband Radars," *Proc. IEEE Geoscience Remote Sensing Symp., IGARSS'98*, Seattle, Washington, vol. 4, pp. 2032–2034, July 1998.

[8] R.T. Lord and M.R. Inggs, "Approaches to RF Interference Suppression for VHF/UHF Synthetic Aperture Radar," *Proc. IEEE South African Symp. on Communications and Signal Processing*, COMSIG'98, Cape Town, South Africa, pp. 95–100, September 1998.

[9] R.T. Lord and M.R. Inggs, "Efficient RFI Suppression in SAR Using LMS Adaptive Filter Integrated with Range/Doppler Algorithm", *Electronics Letters*, vol. 35, no. 8, pp. 629–630, April 1999.

[10] B. Widrow, J.R. Glover, Jr., J.M. McCool, J. Kaunitz, C.S. Williams, R.H. Hearn, J.R. Zeidler, E. Dong, Jr., and R.C. Goodlin, "Adaptive Noise Cancelling: Principles and Applications," *Proc. IEEE*, vol. 63, no. 12, pp. 1692–1716, December 1975.