RADIO FREQUENCY MAPPING: AN ADAPTIVE APPROACH TO MITIGATE SATCOM-RADAR WARNING RECEIVER ELECTROMAGNETIC INTERFERENCE

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ABSTRACT

Military airborne platforms fitted with fire control radars and satellite communications (SATCOM) usually operate at the X band and Ku band frequencies. However, these active transmissions would cause interference with radar warning receivers due to their wider C band to K band radio frequency (RF) spectrum operation. As each system is dedicated to performing a particular function, there is a need to ensure coexistence and interoperability among them by adopting an adaptive approach to mitigate the RF interference. Drawing from past experiences involving a helicopter upgrade programme, this article illustrates a DSTA team’s efforts in implementing a RF compatibility solution to manage SATCOM transmissions.

Keywords: SATCOM, RWR, interoperability, blanking, look-through

INTRODUCTION

A helicopter upgrade programme had called for the additional integration of a radar warning receiver (RWR) and a satellite communications (SATCOM) system. As both systems operate in the same frequency region, the SATCOM transmission would interfere and degrade the sensor’s detection performance due to in-band interference. This could potentially leave the helicopter unprotected during SATCOM transmissions.

To tackle this issue, a team from DSTA reviewed several ideas such as the traditional blanking scheme, look-through scheme as well as installation of fairing to block the line-of-sight (LOS) between the SATCOM and RWR antennas. However, none of the solutions could enable the SATCOM and RWR to coexist and interoperate satisfactorily.

This article presents the interference problem encountered by the mission systems on board the helicopter, the approach to solution development and the technical challenges involved.

INTEROPERABILITY CHALLENGES

The SATCOM system to be installed operates in Ku band, while the RWR is a wide band receiver that detects radio frequency (RF) emitters ranging from C band to K band. Due to the slight overlap in the frequency spectrum, the SATCOM transmission could potentially cause in-band interference with the RWR. If left unaddressed, this interference could degrade the RWR’s sensitivity and affect its operational performance, adversely influencing its threat warning capability as well as increasing the number of false alarms during SATCOM transmission. The close proximity between the antennas of the SATCOM and RWR on board the helicopter also made it challenging to have sufficient RF isolation. To determine the level of interference that the SATCOM transmission had on the RWR, an isolation map was created to establish the severity of interference by quantifying the amount of RF isolation available between the antennas. The extent of isolation is dependent on the amount of SATCOM transmitted power in decibel (dB) that would be received by the RWR after accounting for the free space loss,
installation loss and the antenna gain of both the SATCOM antenna and the RWR antenna, as expressed in the equation (Adamy, 2004):

\[
RF_{isolation} = SAT_{tx-pwr} + Gain_{SAT\_ant} - Loss_{free-space} - Loss_{installation} + Gain_{RWR\_ant}
\]

where \( SAT_{tx-pwr} = \) SATCOM transmitted power (dBm)

\( Gain_{SAT\_ant} = \) Antenna gain of SATCOM antenna (dB)

\( Loss_{free-space} = \) Free space loss (dB)

\( Loss_{installation} = \) Installation loss (dB)

\( Gain_{RWR\_ant} = \) Antenna gain of RWR antenna (dB).

There are a total of four RWR antennas installed on the helicopter – two in front and two at the aft – to provide 360° coverage for RF threat detection (see Figure 1).

For the SATCOM system, there is one antenna installed at the centreline of the aircraft to provide the coverage required to track the geo-stationary satellite for beyond LOS communication. As the installation is symmetrical at the aircraft centreline, only two sets of RF isolation maps had to be generated – one for the front RWR antennas (see Figure 2) and another for the rear RWR antennas (see Figure 3) – with respect to the SATCOM antenna.

The plots in Figures 2 and 3 show the RF isolation in dB for each SATCOM antenna pointing angle in azimuth and elevation in 1° resolution. The interference regions on the RF isolation maps can be determined by using the equation (Browne & Thurbon, 1998):

if \( RF_{isolation} > RWR_{sensitivity} \), no interference is expected.

if \( RF_{isolation} \leq RWR_{sensitivity} \), interference is expected.

where \( RF_{isolation} = \) RF isolation between the SATCOM and RWR (dBm)

\( RWR_{sensitivity} = \) Sensitivity of the RWR at the antenna (dBm).

In Figures 2 and 3, the interference regions are colour-coded in orange and red. As expected, the interference region is seen when the SATCOM antenna is pointing towards the helicopter body at an elevation angle of between 0° to 30°. However, based on the area of operations for the helicopter and the fact that a geo-stationary satellite orbits approximately 35,800km directly over the equator, the SATCOM antenna would only be traversing between 60° and 90° in the elevation plane in order to establish and maintain communication with the satellite. As such, the interference zone could be reduced and localised in terms of the SATCOM antenna’s pointing angle in the azimuth plane between the region of 80° to 90° (refer to the circled regions in Figures 2 and 3). The initial RF isolation
maps showed that about 15% of the coverage would not have sufficient RF isolation, and interference between the SATCOM and RWR systems could be expected. The interference also did not take into account the attenuation from helicopter body blockage as the RF isolation calculation is based purely on the LOS between the SATCOM and RWR antennas, as well as their locations on the helicopter. The actual level of interference could only be established by conducting a verification test on the helicopter with the systems installed.

**RF COMPATIBILITY SOLUTIONS STUDIED**

A number of solutions were studied and assessed by the team to be inadequate in addressing the interference issue while meeting operational requirements.

**Blanking**

The traditional blanking method involves the sending of a blanking pulse from the SATCOM system to the RWR via a blanking line during SATCOM transmission (Skolnik, 2001). The RWR would either not process the received signal or refrain from using its receiver during the blanking period, thereby avoiding false detection of onboard emitters (see Figure 4). This solution typically works when the transmitting source is not transmitting all the time or has a low duty cycle. However, SATCOM systems transmit a very high duty cycle signal almost similar to a continuous wave signal. Thus, this approach would render the RWR virtually ‘blind’ whenever the SATCOM system is in transmission, preventing it from detecting any actual RF emitters in the SATCOM transmission band.
Look-through

In the look-through method, a window of opportunity is provided for the RWR to perform its detection of RF emitters – prompted by a look-through line between the SATCOM system and the RWR – during the SATCOM transmission period.

The SATCOM system uses Code Division Multiple Access for its transmission and transmits in frames of data blocks. The SATCOM system can assign one data frame (measured in tens of milliseconds) to the RWR as the look-through window before it begins its transmission (see Figure 5). This process is repeated periodically until the SATCOM system completes its transmission when the pilot releases the Push-To-Talk (PTT) switch.

Although the look-through method provides the RWR with an opportunity to detect RF emitters during SATCOM transmission, the RWR’s Probability of Intercept (POI) performance would be affected. While the RWR might be able to detect tracking RF emitters because of the longer time-on-target, it would not achieve the required POI for a scanning type of RF emitter. To improve POI performance against scanning RF emitters, the SATCOM system would need to extend the look-through window to beyond one data frame to allow more time for the RWR to detect the threat. Depending on the scanning rate of the RF emitter, the duration of the look-through window should be at least one scan rotation of the RF emitter (which could be as long as a few seconds). However, it was demonstrated via simulation that the voice quality of the SATCOM transmission would be impacted if more than one frame of data was lost, which is an operationally undesirable outcome.

RF Isolation/Shielding

Another method to improve the RF isolation between the SATCOM antenna and the RWR antenna is to install metal fairing on the helicopter to provide LOS blockage between the two systems’ antennas. However, it was assessed that the fairing might affect the SATCOM antenna beam pattern and eventually the system performance. The additional fairing would also increase drag and affect the helicopter’s aerodynamic performance. Furthermore, the installation of fairing on the helicopter was constrained by space availability and the size of the fairing, and this would require further study from the helicopter manufacturer. However, adding fairing

![Figure 4. Blanking pulses generated (top) and RF pulses received (bottom)](image)

![Figure 5. Look-through window during SATCOM transmission](image)
would be a feasible solution for a new helicopter as it could be incorporated as part of the upfront design without any adverse impact on project cost and schedule.

The team also explored another option to improve the RF isolation between the SATCOM and RWR antennas. From the simulation that was used to generate the RF isolation map, it was determined that the expected interference as shown in the map was due to the RWR antenna picking up the side-lobe radiation of the SATCOM antenna. As the SATCOM antenna would normally be pointing in the region of 60° and 90° due to the helicopter’s area of operations, it was initially proposed to incorporate radar absorbing material (RAM) on the inner surface of the SATCOM antenna radome to block its side-lobe transmission and increase the RF isolation. However, the type of RAM available then could only provide up to 20dB of attenuation, which was insufficient for the suppression of the SATCOM transmission. While additional metal blanking would mitigate this issue, assessment of the internal space available in the radome led to the conclusion that there was not enough clearance between the radome surface and the SATCOM antenna to install both the RAM and metallic barrier.

**SOLUTION USING OPERATIONS MANAGEMENT**

The team studied and subsequently adopted the system-to-system cooperative operations management approach to alleviate the SATCOM-RWR interference problem. For the SATCOM system, the possibility of limiting the interference by regulating its transmission was explored. The RWR's robustness under interference conditions was also improved via new processing algorithms.

**SATCOM Interference Control**

The regions of potential interference caused by the SATCOM system during its transmission were observed to be localised based on the SATCOM antenna pointing angle. As such, the proposed solution was to create an interference map defining the interference zone based on the SATCOM antenna pointing angle in azimuth and elevation with a 1° resolution. The results would be tabulated in a 90 by 360 matrix to be programmed into the SATCOM system. When the SATCOM antenna is pointing in the interference regions, it is termed as “in-zone”; if the SATCOM antenna is pointing in the non-interference regions, it is termed as “out-zone”. During operations, the SATCOM system would automatically inhibit transmission when its antenna is pointing in the “in-zone” region and the PTT button is pressed. At the same time, the SATCOM system would indicate to the pilot that its antenna is pointing in the “in-zone” region. SATCOM transmission is allowed when the SATCOM antenna is pointing in the “out-zone” region as the RWR would not pick up the transmission. In addition, the pilot could choose to overwrite the automatic “in-zone” SATCOM transmission inhibition depending on real-time operational needs. Thus, this approach would allow both the SATCOM system and the RWR to coexist and interoperate, with the pilot having the option of overriding the automatic transmission inhibition if required.

**Enhancement of the RWR**

To handle unwanted residual interference, the DSTA team incorporated an adaptive thresholding mechanism with detection missions into the RWR’s processing algorithm. The existing digital-receiver based RWR channelised architecture and its interference handling mechanism would allow the RWR to maintain good sensitivity and POI at frequencies unaffected by the SATCOM interference. The RWR is able to achieve this as its digital receiver is broken down into a few receiver bands covering the C band to K band range of frequencies. Additionally, the RWR can be programmed with a default threshold in a typical low-noise environment. When interference is detected, for example, due to SATCOM transmissions, the RWR software would measure the interference and isolate the affected receiver band. The threshold for the affected band would be increased slightly above the interference level, while the threshold for the other receiver bands remains at the default level. This would allow the RWR to maintain maximum sensitivity and POI for the unaffected receiver bands.

For the affected receiver band, the RWR is able to further trigger a special mission that uses adaptive thresholding with a narrower band receiver. The narrower band receiver can determine the threshold with a more selective bandwidth in the MHz range to capture the interference and minimise its effect on threat detection. With this, the detection threshold is higher at the SATCOM transmission frequency than at frequencies that do not experience interference. Hence, as long as the frequencies of the RF threat and the SATCOM transmission signals do not coincide, the RWR would still be able to detect threats that fall within the affected frequency band, even if the power level of the threat is lower than the peak SATCOM signal power (see Figure 6).

**CONCLUSION**

The in-band interference between the SATCOM system and RWR is a typical RF compatibility problem on board helicopters. Applying traditional solutions such as blanking,
look-through and fairing shield cannot resolve the interference issue and meet the operational requirements concurrently. An innovative approach was hence conceived by the DSTA team to address the interference problem by implementing a RF isolation map to limit the impact of interference and improve the RWR’s detection robustness to handle such an environment. This system-to-system cooperative management approach was the first of its kind used in the handling of in-band interference issues. Furthermore, it avoided changes to the helicopter’s installation or redesign of RWR hardware which would be costly and potentially affect the project schedule. The proposed solution is also suitable for other platform types equipped with SATCOM and RWR (or passive receiver).

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REFERENCES


ENDNOTES

1 An elevation of 90° means that the SATCOM antenna is pointing up, while an elevation of 0° means the antenna is pointing horizontally. An azimuth of 0° indicates that the SATCOM antenna is pointing forward towards the nose of the aircraft. Negative and positive degree azimuth means that the SATCOM antenna is pointing towards the left and right side of the aircraft respectively.

BIOGRAPHY

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