SURVEILLANCE AND CONFLICT RESOLUTION SYSTEMS PANEL (SCRSP)

TENTH MEETING
WG-A

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WG-A Agenda Item 9
Any Other Bussiness

Impact of ATC transponder transmission to onboard GPS-L5 signal environment

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SUMMARY

This is an information paper on the measured interference from ATC transponder to onboard GPS-L5 / Galileo-E5 receiver.

The onboard frequency spectrum in L5/E5 band is measured airborne with Beechcraft B99 by ENRI. The original purpose was the measurement for the interference by DME reply signals in this band. The transmission signals of onboard ATC transponder is also observed in this band even after adding band-pass filters to guard this band.

The essential measure of interference to L5/E5 signals is the duty ratio of interfering pulse with exceeding an power level to trigger the pulse blanker processing in L5/E5 receiver. It is estimated to be less harmful than that of DME/TACAN replies from ground.

It should be noted that the future signal environment have to be estimated and examined for L5/E5 operational signal environment.

References

[1]. ICAO: "ANNEX 10", volume IV, amendment 77, 2003

[2]. RTCA SC-187: “MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIR TRAFFIC CONTROL RADAR BEACON SYSTEM/MODE SELECT (ATCRBS/MODE S) AIRBORNE EQUIPMENT”, RTCA/DO-181C, June 12, 2001

[3]. RTCA SC-159: “Assessment of Radio Frequency Interference Relevant to the GNSS L5/E5a Band”, RTCA/DO-292, July 29, 2004

1. Introduction

1.1 The frequency of GPS-L5 and Galileo-E5 signals are assigned in Aeronautical Radio Navigation Service, ARNS, band to share the spectrum with DME, TACAN and some other radio systems. The L5/E5 signals are expected to enhance the GNSS performance in future.

1.2 The L5/E5 system design takes the interference from these radio systems into account. The receiver with Automatic Gain Control, AGC, assisted by pulse blanker processing will keep the satellite signals into its dynamic range by rejecting parts of signal which is jammed by strong pulse interference. AGC will not control correctly without blanking pulse interference with much higher power than L5/E5 signals.

1.3 On the other hand, the pulse blanking degrades system performance with too many rejecting parts by blanking. The signal acquisition and tracking performance of L5/E5 receiver is governed by effective SN ratio of received signal. The SN ratio is degraded by pulse blanking processing as a function of pulse duty ratio at the trigger level.

1.4 This paper provides the information on the measured data for onboard signal environment in L5/E5 band. The measured pulse interference from ATC transponder is focused in this paper.

2. Measurement for onboard signal environment

2.1 ENRI is conducting a series of flight experiments to measure the signal environment in ARNS band including the part for L5/E5. Beechcraft B99 is used for first onboard measurement during flight in December 2005.

2.2 The first experiment was carried out with a handheld spectrum analyser to measure the power spectrum in L5/E5 band and to measure the waveform of interfering signals as shown in figure 1.

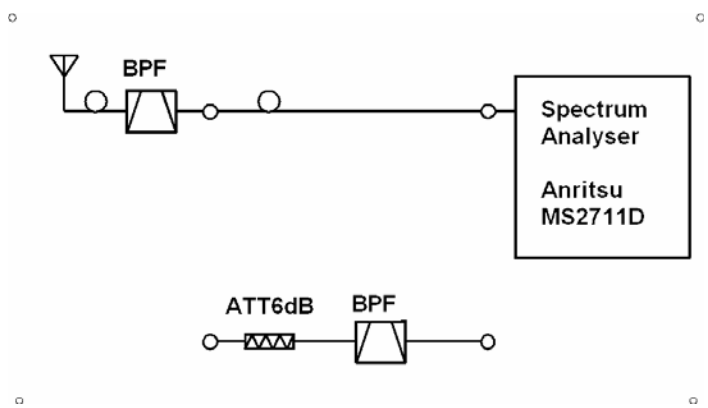

Figure 1 Equipments for onboard measurement

2.3 The Band Pass Filter, BPF in this figure, is designed to have centre frequency of pass band at 1176MHz, i.e. the frequency for GPS-L5 and Galileo-E5a. Its bandwidth is 30MHz at -3dB point. The loss in the pass band is less than 1dB. It has about 60dB rejection at 1138MHz and more at 1090MHz.

2.4 The top and bottom antennas equipped with Beechcraft B99 are used for measurement. They are the "blade" antennas which are designed originally for DME interrogator and ATC transponder.

3. Interference from ATC transponder

3.1 Onboard signal environment including L5/E5 band is plotted in figure 2 and 3. One or two filters ware used for each measurement in figure. These figures are the result of max-hold mode measurement for some minutes to display the maximum received power in the band.

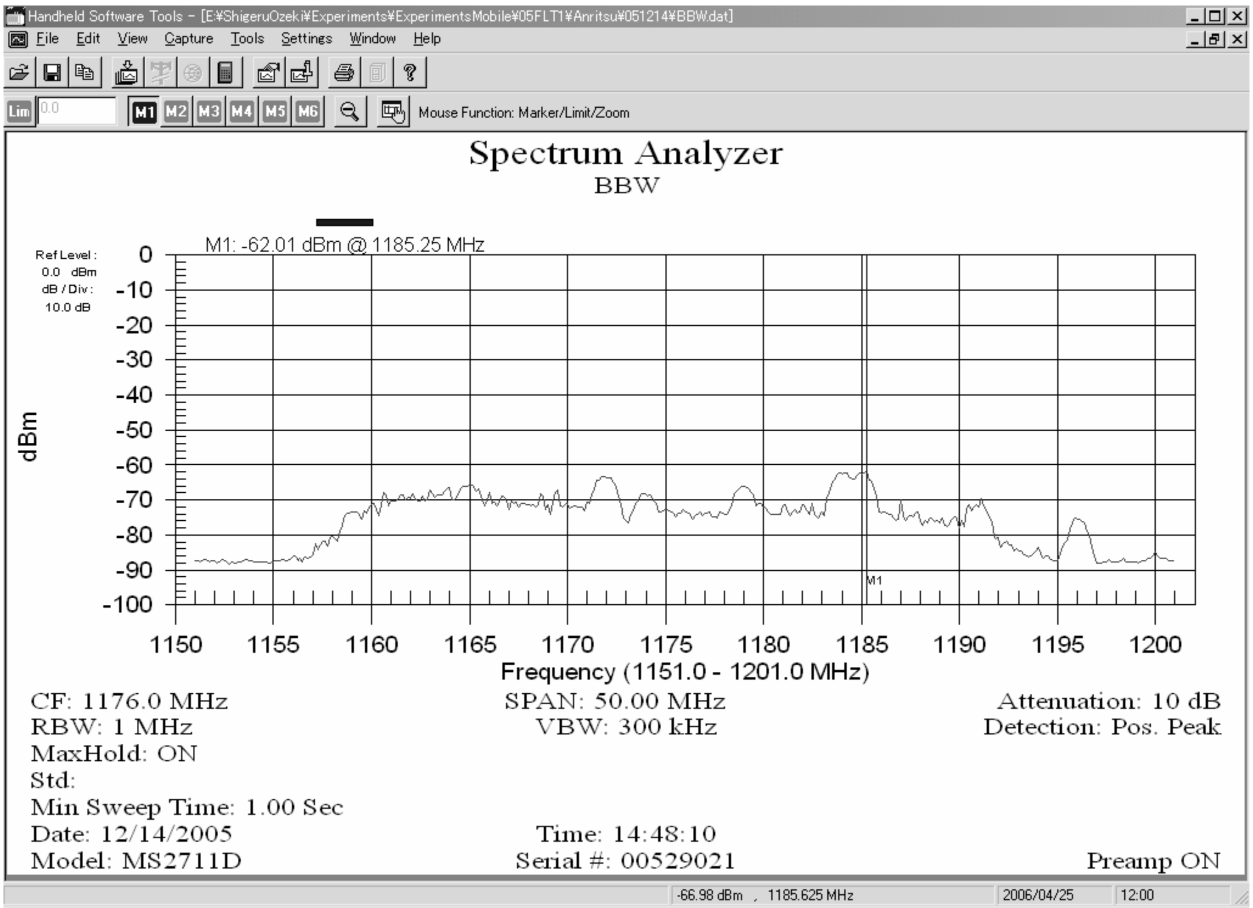

Figure 2 Measured power spectrum with a BPF

3.2 The spectrum of reply signal from ground DME is observed as Gaussian curve with centring for each reply RF frequency. The low level part of spectrum is buried by "noise" in BPF pass band.

3.3 The "noise" level in BPF pass band is same between these figures except with level shifting by 6dB attenuator and by additional loss of circuits including additional BPF. This means that the measured "noise" power is due to emissions in this band.

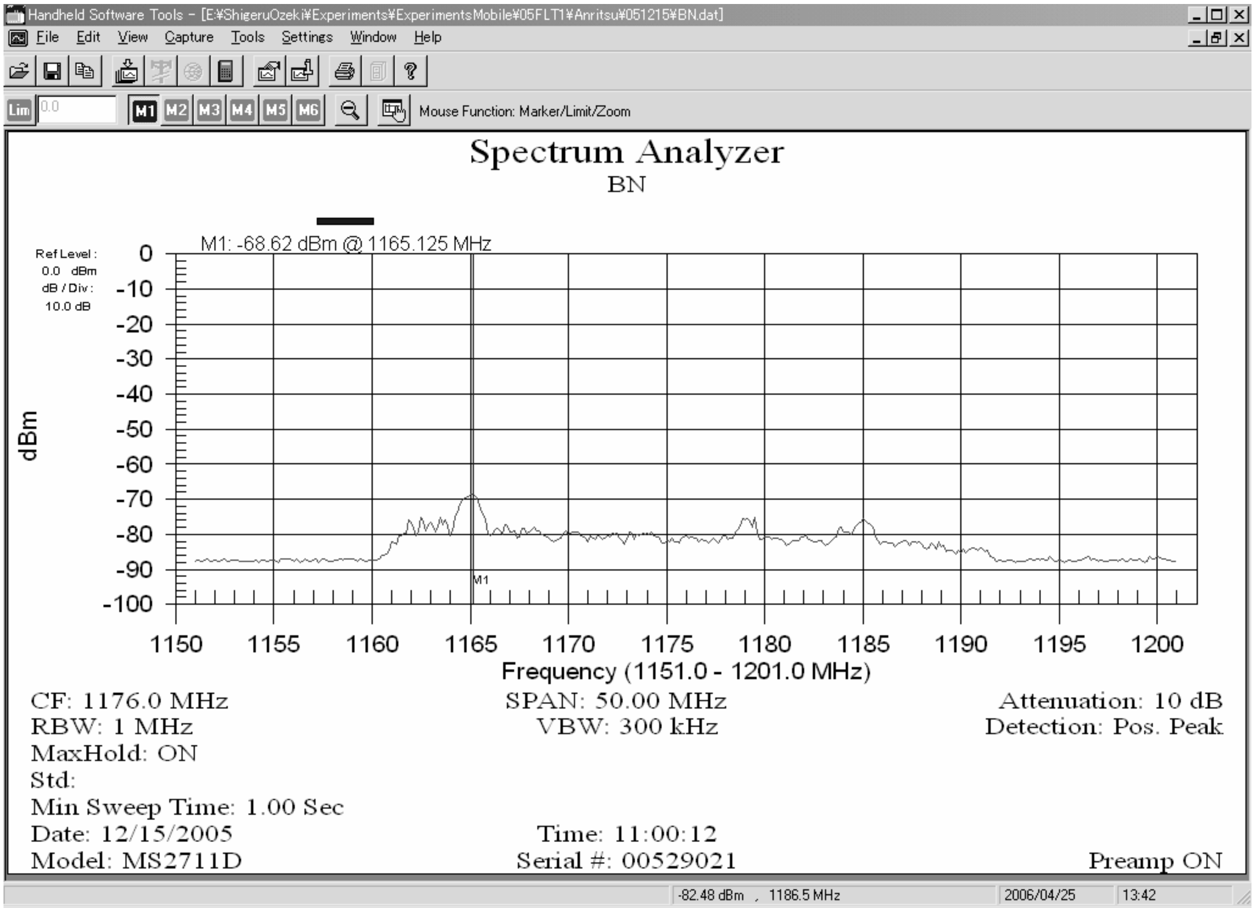

Figure 2 Measured power spectrum with two cascaded BPFs

3.4 The waveform of "noise in pass band" is measured with a BPF as in figure 4. The zero-span mode recording was used for this measurement without max-hold function. The waveform is distorted by the band width limitation of spectrum analyser by 3MHz. The timing of pulse reception is same with ATCRBS reply in mode A with coding 7302 for DBC. The DBC was 7302 for our Beechcraft B99 on the day of measurement.

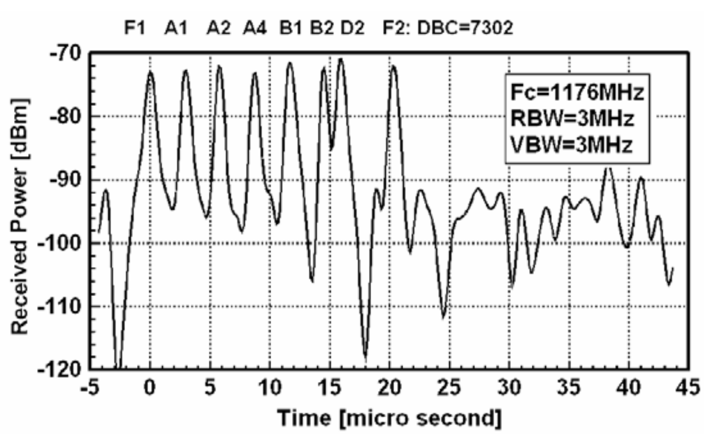

Figure 4 Interference by ATC transponder in L5/E5 band measured with 3MHz-BW

4. **Analysis of measured results**

4.1 The measured interfering signal in L5/E5 band was replies from ground DME and onboard ATC transponder. The measured power level of pulse interference by ATC transponder reply signal is satisfied with applicable standards for unwanted emission. The emission of ATC transponder in this band is specified by ICAO and by RTCA as explained in appendices A and B for each. The power reduction in L5/E5 band was more than 70 dB from the power level at 1090 MHz. The received power of ATC transponder transmissions at 1090 MHz was about 3dBm without BPF.

4.2 The coupling between antennas can vary the interference level. The distance between top antennas for ATC transponder and for measurement was about 1.8 meter or 6 feet on Beechcraft B99. Also, the result may be changed by onboard transponder. Our Beechcraft B99 is equipped with Collins TDR-94D mode S transponder.

4.3 The power level of pulse interference by ATC transponder may exceed the trigger level for pulse blanker processing for L5/E5 receiver even with 20dB reduction by the polarization loss of L5/E5 antenna. The trigger level is assumed to be -90dBm or so.

4.4 The effective SN ratio at L5/E5 receiver is degraded by pulse blanking processing as a function of pulse duty ratio at the trigger level. The pulse duty ratio by ATC transponder transmissions is obtained by summing the duty ratio for each transmission mode. The duty ratio for each transmission mode is obtained by multiplying its transmission rate and the duty ratio of a reply with this mode.

4.5 The duty ratio is about 0.0037 in the worst case with assuming current signal environment in the Tokyo Airspace. In the Tokyo Airspace, the maximum reply rates are observed by onboard measurement at 10,000ft altitude in 2004 as about 350 replies per second for ATCRBS and 50 replies per second for mode S short with averaging in 100 seconds measurement duration.

4.6 The pulse interference by ATC transponder transmissions is less harmful than that of DME reply signals. The duty ratio with the reply signal of ATC transponder is less than one-tenth of that of DME reply signals, 0.18, with assuming ten interfering beacons by 1,500 ppps transmissions and blanking for 6 micro second for each pulse.

4.7 It should be noted that future signal environment in this band have to be estimated and examined for L5/E5 operational signal environment.

5. **Conclusions**

5.1 WG-A members are invited to note this information.

Appendix A

ICAO ANNEX10, volume IV, amendment 77

3.1.2.2 REPLY SIGNALS-IN-SPACE CHARACTERISTICS

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3.1.2.2.2 *Reply spectrum.* The spectrum of a Mode S reply about the carrier frequency shall not exceed the limits specified in Figure 3-5.

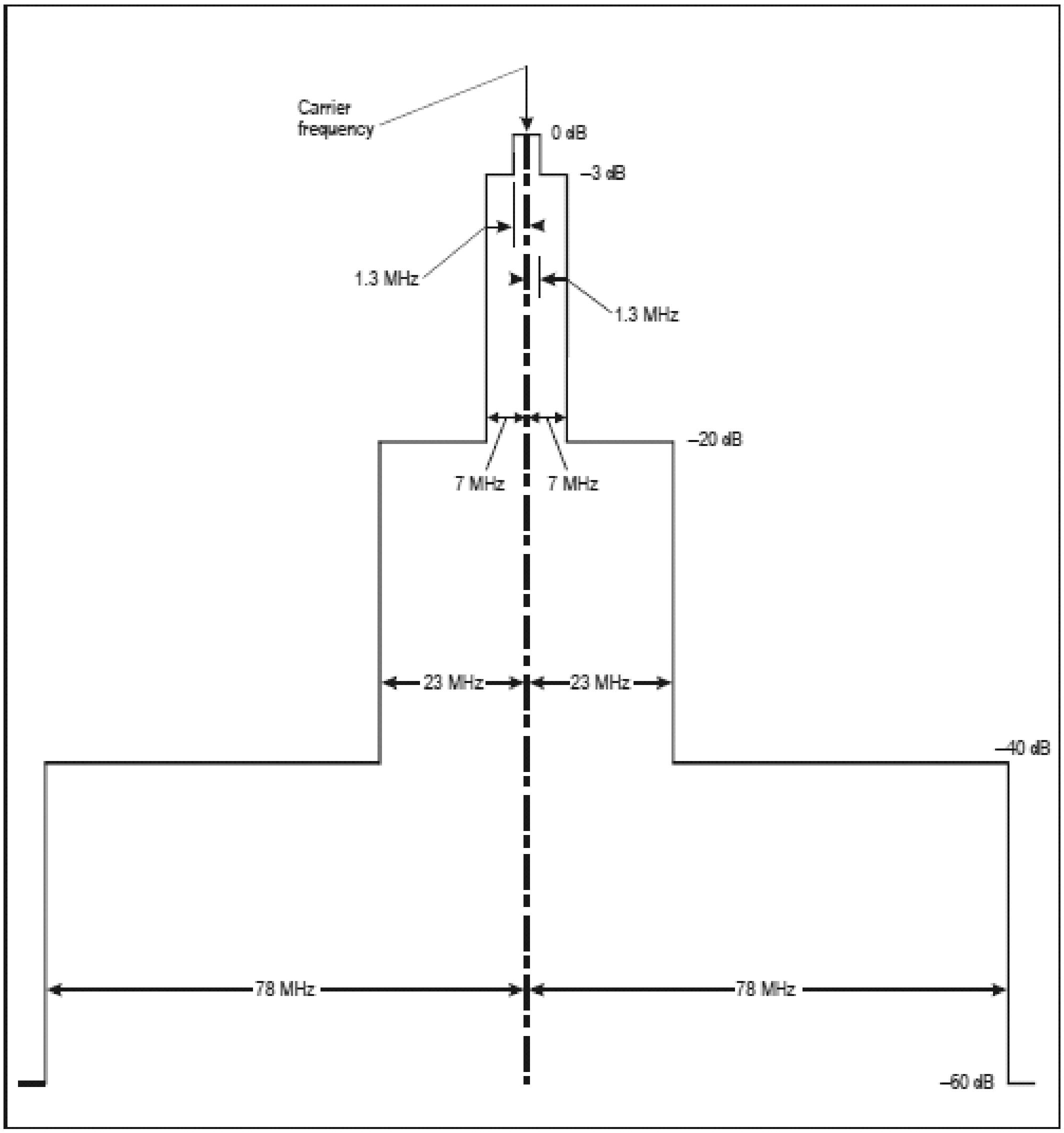

Figure 3-5. Required spectrum limits for transponder transmitter

Note.— This figure shows the spectrum centred on the carrier frequency and will therefore shift in its entirety plus or minus 1 MHz along with the carrier frequency.

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3.1.2.10 ESSENTIAL SYSTEM CHARACTERISTICS OF THE SSR MODE S TRANSPONDER

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3.1.2.10.2.1 *Inactive state transponder output power.* When the transponder is in the inactive state the peak pulse power at 1 090 MHz plus or minus 3 MHz shall not exceed –50 dBm. The inactive state is defined to include the entire period between transmissions less 10-microsecond transition periods preceding the first pulse and following the last pulse of the transmission.

Note.— Inactive state transponder power is constrained in this way to ensure that an aircraft, when located as near as 185 m (0.1 NM) to a Mode A/C or Mode S interrogator, does not cause interference to that installation. In certain applications of Mode S, airborne collision avoidance for example, where a 1 090 MHz transmitter and receiver are in the same aircraft, it may be necessary to further constrain the inactive state transponder power.

3.1.2.10.2.2 *Spurious emission radiation*

Recommendation.— *CW radiation should not exceed 70 dB below 1 watt.*

Appendix B

RTCA SC-187: “MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIR TRAFFIC CONTROL RADAR BEACON SYSTEM/MODE SELECT (ATCRBS/MODE S) AIRBORNE EQUIPMENT”, RTCA/DO-181C, June 12, 2001

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2.2.3.3 Unwanted Output Power

When the transponder transmitter is in the inactive state, the RF output power at 1090 ±3 MHz at the terminals of the antenna shall not exceed -50 dBm. The inactive state is defined to include the entire period between ATCRBS and/or Mode S transmissions less 10-microsecond transition periods, if necessary, preceding and following the extremes of the transmission.

Note 1: This is necessary to ensure that Mode S-equipped aircraft operating as near as 0.1 nmi to an ATCRBS or Mode S sensor will not degrade the operation of that sensor. Also, an on-board 1090 MHz receiver, e.g., a collision avoidance system (CAS) installation, may be interfered with by CW radiation from the transponder. Therefore, lower unwanted CW power output may be required for use in aircraft installations where sufficient isolation cannot be achieved.

Note 2: If the transponder is used in conjunction with TCAS equipment, the RF power in the inactive state at 1090 MHz at the terminals of the Mode S transponder antenna shall not exceed -70 dBm.