AERONAUTICAL SURVEILLANCE PANEL (ASP)

FIRST MEETING
WG-A

Kobe, November, 2006

WG-A Agenda Item 5.7
Task for ASP
Task 5: RF issues on 1030/1090 MHz

Signal Environment Measurement with Long Time Waveform Recorder

(Presented by Shigeru Ozeki)
(Prepared by Shigeru Ozeki, Takuya Otsuyama)

SUMMARY

This is an information paper on the measurement of signal environment with long time waveform recorder and an example of its application.

In 2000, a long time waveform recorder has been introduced to ENRI for the measurement of 1030/1090 MHz signal environment. In 2002, it is applied to investigate the reason of excess reply transmission from hovering helicopter above a helipad in the Sendai Airport.

ENRI is now using some types of waveform recorder to investigate the signal environment in ARNS band including 1030/1090 MHz.

References

[1]. ICAO: “ANNEX 10”, volume IV, amendment 77, 2003
[2]. S. Ozeki: “Comparison of statistical model for fruits”, ICAO/SICASP/WG2-25, IP-601, October, 1996
[3]. S. Ozeki: “1030MHz signal measurement in Japan”, ICAO/SRCSP/WG-A, IP-A1-18, April, 2001.
[4]. S. Ozeki: “Effect of transponder decoder performance on the 1090MHz signal environment”, ICAO/SRCSP/WGA, WP-A5-173, April, 2003.
[5]. S. Ozeki: “Transponder anomalies observed with airborne wave form measurement”, ICAO/SRCSP/WGA, WP-A6-220, November, 2003.
[6]. S. Ozeki: “Reply failure to low power interrogations”, ICAO/SRCSP/WGA, WP-A8-14, May, 2005.
[7]. S. Ozeki: “Impact of ATC transponder transmissions to onboard GPS-L5 signal environment”, ICAO/SRCSP/WGA, WP-A10-18, May, 2006.

1. Introduction

1.1 ANC has assigned following task to ASP on May 2006.

> 5) Investigate and report on the radio frequency (RF) pollution problem associated with the use of 1030/1090 MHz frequencies.
>
> Report : 2007

1.2 First, this paper provides the information on the history of measurement method for signal environment in these channels by introducing some equipment in ENRI. ENRI has been using various equipments to measure the signal environment as follows.

1.3 Then, his paper provides information on signal environment measurement with focusing on the long time waveform recorder. The long time waveform recorder in this paper is defined as a digital waveform recording system with the required throughput to provide continuous recording of digital data for sufficient length of time from some seconds to more than some hours.

2. History of signal environment measurement in ENRI

2.1 The experimental mode S transponder has been used to measure the 1030 MHz signal environment since 1999. The transponder decoder was modified to pick up the decode triggers for each type of interrogation signal, and they ware fed to pulse counter for each. This measurement gives us the information how the signals in environment are decoded by mode S transponder. This measurement gave us some indication about the airspace where the signal count deviates from our estimation significantly. For example, excess interrogation rate has been observed around SSR with this method. It is also observed that the transponder decoder may fail to discriminate interrogation mode for low power interrogations with their power close to decoder MTL. Those results have been reported to SCRSP/WG meetings since 2000.

2.2 Similar measurement has been conducted for 1090 MHz channel to evaluate the statistical model of asynchronous interference onto mode S extended squitter. In this case, 1090MHz receiver and reply signal decoders were used to count the received signals with gating decode triggers by time equivalent to the duration of mode S extended squitter. The result was reported to SICASP/WG2 meetings in 1996.

2.3 The various wave form recorder has been used to analyse the signal environment that gives abnormal count at decoder output. If the decoder output gives us an indication of abnormal operation, then it is required to observe the waveform of received signals.

2.4 ENRI researchers have experiences to measure the waveform of 1030/1090 MHz receiver output with waveform recorders. For example, in 2004, the waveform of onboard 1030/1090 MHz receiver output have been recorded once every second during flight to investigate the signal environment in Japanese airspace. Each record contains AD converted waveform of log video outputs for about 200 micro seconds.

2.5 ENRI is now using some types of waveform recorder to investigate the signal environment in ARNS band including 1030/1090 MHz.

2.6 In 2000, a long time waveform recorder has been introduced to ENRI for the measurement of 1030/1090 MHz signal environment. In 2002, it is applied to investigate the reason of excess reply transmission from hovering helicopter above a helipad in the Sendai Airport.

3. Measurement of signal environment with long time waveform recorder

3.1 The first long time waveform recorder for ENRI is specified to measure 1030/1090 MHz signal environment for more than two rotations of SSR antenna for en-route surveillance. This recording system was introduced to investigate the interference onto signals in these channels.

3.2 The first long time waveform recorder has following specification. As a result, this system can record 2 channels of log video outputs from receiver at once with 16 bits resolution and with 10 MHz sampling rate.

AD converter	resolution	16 bits
	Sample rate	10MHz for 2 ch operation
Memory	Sharing	256 M samples for each 2ch

3.3 An example of snap shot picture during measurement is shown in figure 1.

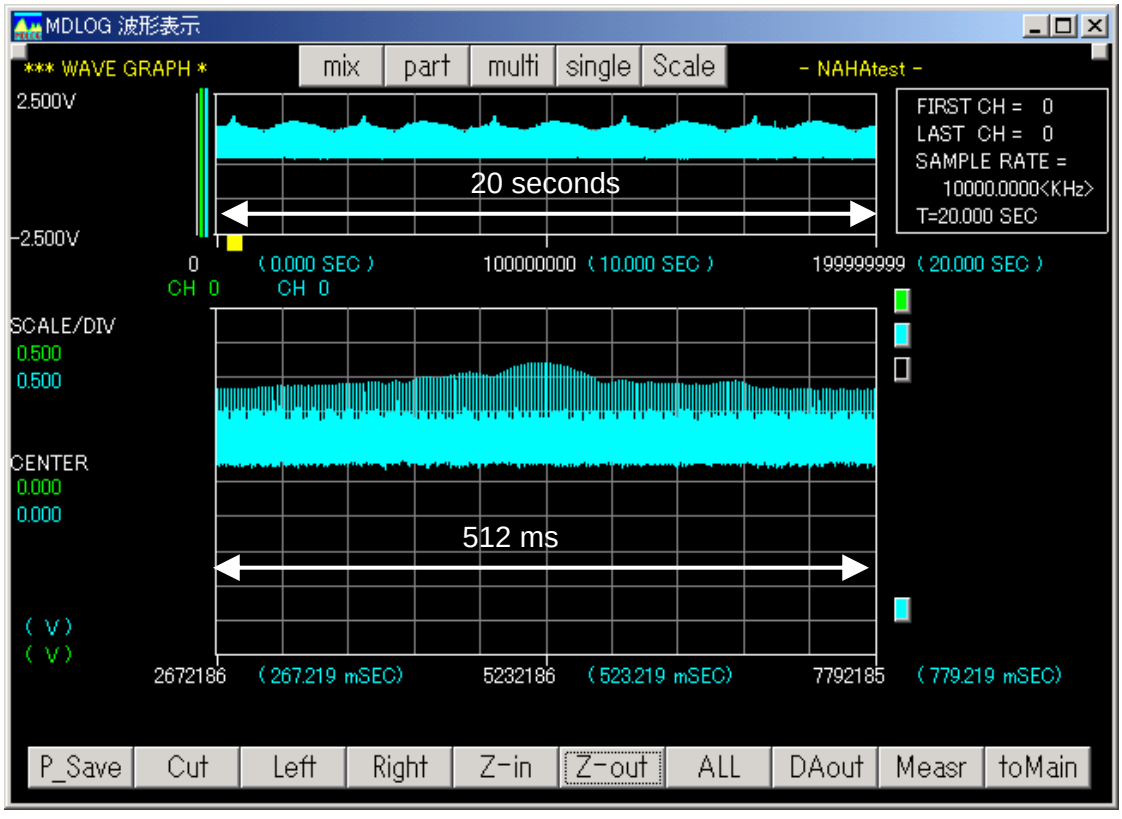

Figure 1 Example of received waveform in 1030 MHz channel at the Sendai Airport

3.4 The receiver antenna was set at the apron in front of ENRI branch office in the Sendai Airport to record this waveform. These cobalt lines in figure represent the recorded amplitude of log video output of 1030 MHz receiver. The lateral axis represents the time.

3.5 The upper window in this figure displays log video output waveform for 20 seconds. The received waveform has 5 peaks with associating to receiving the transmission from main beam of SSR antenna with 5 times rotations in 20 seconds.

3.6 The lower window in this figure displays a part of waveform in the upper window, i.e. zoom in. The vertical cobalt lines in the lower window are the waveforms interrogation signals from SSR. With zooming in more for time scale, the interrogation signal was observed like in figure 2.

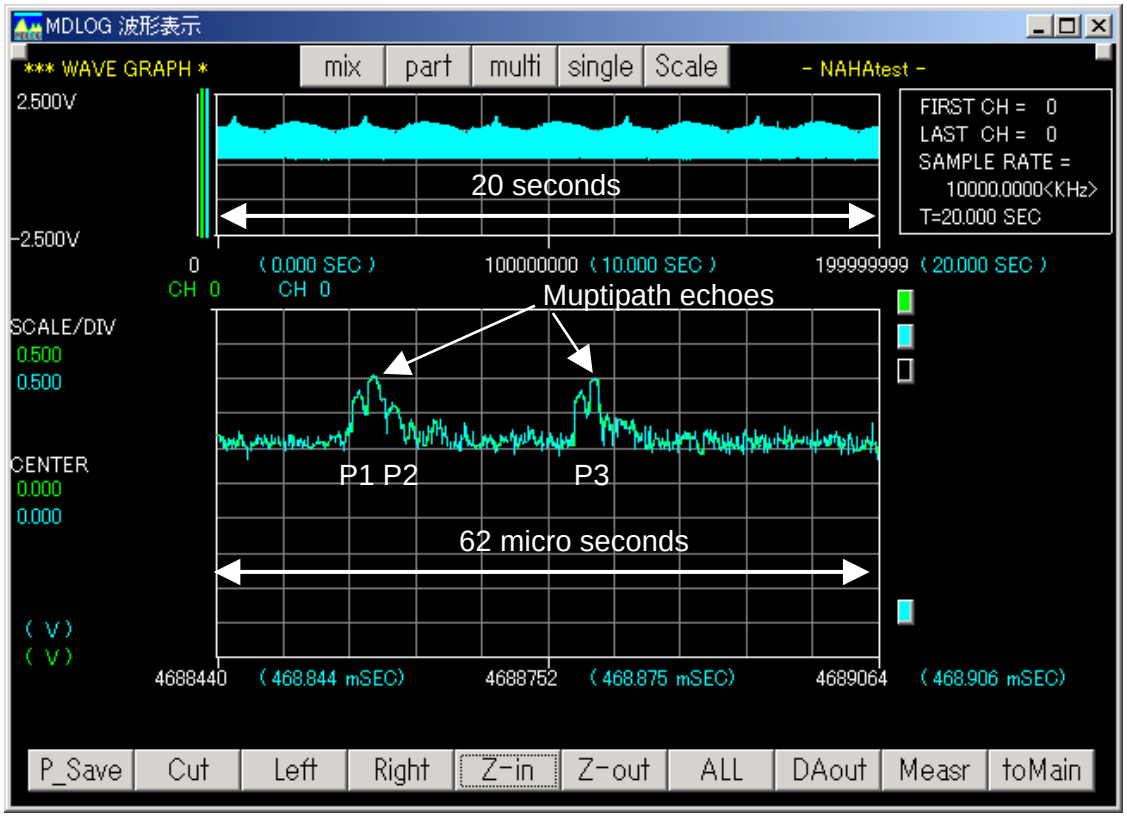

Figure 2, Zooming in to observe each interrogation signal pulse

3.7 In this case, the pulses of mode C interrogation signal with its multipath echoes are displayed in the lower window. The multipath echoes of P1 and P3 have higher power than that of direct path signals. The direct path signal by side lobe transmission of SSR antenna may be weaker than the multipath echo of main beam transmission.

3.8 The direction of reflecting object from SSR is calculated easily by reading out the time difference, say Td, between the time to receive signals from main beam and the time of receiving multipath echo of main beam. This can be done with upper window. The difference of direction between the receiving antenna and the reflecting object is 360 Td / T, where T is the rotating time of SSR antenna.

3.9 This observation of waveform gave us the answer of a question why excess replies are transmitted by ATC transponder. For example, the transponder of hovering helicopters around this measurement point replies ATCRBS signals more than 100 Hz, because the transponder decoder cannot detect P2 pulse for SLS with filling the gap between P1 and P2 by strong multipath echo of P1.

4. Second generation of long time waveform recorder

4.1 ENRI has already introduced some types of waveform recorder with high throughput ring buffer memory and interface more than 10M samples per second. This group of waveform recorders are used to monitor the signal environment in 1090 MHz band. The results will be reported in future.

5. Next generation of long time waveform recorder

5.1 ENRI is conducting a series of flight experiments to measure the signal environment in ARNS band including the part for GPS-L5 and for GALILEO-E5. Beechcraft B99 is used for first onboard measurement during flight in December 2005. 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 reported in SCRSP/WG-A tenth meeting in Montreal.

5.2 ENRI is now developing the wide band and long time waveform recorder for the measurement of signal environment in more than 30MHz band width. This specification will be sufficient to measure the interference to GPS-L5 signal at once. Also, it will be applied to measure the signal environment for various radio systems including GALILEO-E5, mode S, UAT, and so on.

5.3 An example of measured data is in figure 3.

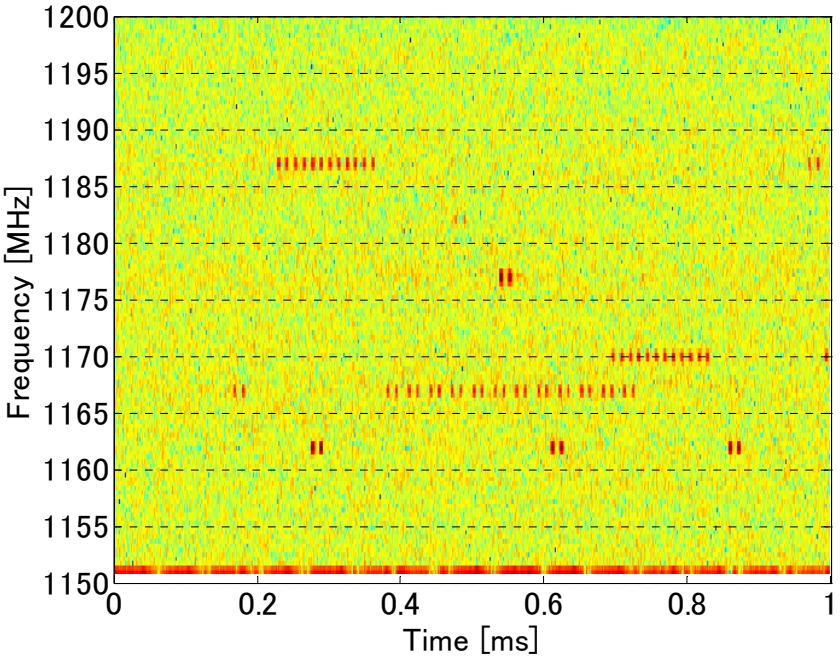

Figure 3, Measured power spectrum with a BPF

5.4 This figure is a result of time-frequency analysis for a record of data from onboard measurement with the waveform recorder under development. The waveform of IF out put of GPS-L5 band test receiver was recorded for 1 second every minute with 100 MHz sampling rate and 12 bits resolution. This data was measured at 13000ft high close to IWAKI VOR/DME in Japan on October 27, 2006.

5.5 In figure 3, signal amplitude is represented by color. The noise floor is in yellow and green level. The most pulse signals are in red level. The north burst pulse chains of TACAN are found at 1170MHz and 1187MHz. They are assembled with 12 gaussian pulses. The ID tone pulse chain has been found at 1167 MHz. It is assembled with 12 gaussian pulse pairs. In addition, DME/TACAN beacon reply signals are found in 1162 MHz and 1177 MHz. The signal in 1151 MHz is the weak leakage of local oscillator of test receiver and DC component after FFT.

5.6 The data will be used to confirm the system design of waveform recorder, to develop a group of software for signal analysis and to perform preliminary analysis for signal environment. ENRI is now developing a waveform recorder with higher throughput more than 100 M samples per second with 16 bits resolution.

6. Some observations

6.1 The application of waveform recording will be useful for signal environment analysis. Especially, it will be useful to investigate the problems of radio system operation in the field. Also, the measured data will be useful to evaluate the decoder operation under real signal environment by feeding measured data to them.

6.2 The issue of waveform analysis will be the throughput of data processing system and huge storage for measured data. In addition, we need decoder model in data processing software to detect signals and to count them. The quality of this “software decoder” may affect the result of signal environment evaluation.

7. Conclusions

7.1 ASP/WG members are invited to note the information in this paper. ENRI is prepared to measure 1030/1090 MHz signal environment. In addition, ENRI is developing a wide band and long time waveform recorder to investigate signal environment and radio system operations with regarding new signals in ARNS band.