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Windshear Radar Calibration, 1992 Flights: Transmitter Power and Receiver Gain Stability

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I. INTRODUCTION

In 1992, the Antenna & Microwave Research Branch at the NASA Langley Research Center conducted the second year of experimental Airborne Doppler Windshear Radar flights using Langley's Boeing 737 aircraft, N515NA. This memorandum presents the results of the pre-flight radar calibrations, including transmitter power and receiver system gain and noise.

Two series of experimental flights were conducted, one series over Stapleton Airport at Denver, Colorado,and one series over Orlando International Airport at Orlando, Florida. Before each flight, the radar was calibrated using an IFR test set [1], which measured power from the radar transmitter and transmitted echo pulses at pre-set power levels to the radar receiver, allowing receiver gain and noise to be calculated from the recorded signals. The methods of measurement and calculation have been documented in a previous memorandum [2], which describes the radar calibrations for flights conducted in 1991; therefore, only a brief discussion of the methods appears below. All measurements recorded in this document apply to Receiver/Transmitter (R/T) unit #2, which was flown exclusively in 1992.

II. QUANTITIES MEASURED OR CALCULATED

A. <u>Transmitter Power and Power Amplifier Gain</u>

The airborne Windshear Radar was built to transmit pulses at either a low peak power of 200 watts or a high peak power of 2000 watts, nominally. The higher transmitting power was achieved by the use of, effectively, an optional 10-dB amplifier. In pre-flight checks, the transmitter power was measured at both levels with the IFR test set. The actual gain of the 10-dB amplifier was then calculated.

Calibrations were performed in radar modes 6 and 7, which are described completely in Appendix A. The primary difference between the two modes was the width of the pulse, mode 6 having a pulse width of 0.96 μs and mode 7 having a pulse width of 1.92 μs.

B. <u>Receiver Gain</u>

Except for the changing attenuation provided by the Automatic Gain Control (AGC) system in the receiver, the receiver gain is relatively constant. This constant receiver gain was calculated from I,Q voltages and AGC attenuation values recorded when the IFR input power to the receiver had been -50 dBmW, well above the receiver noise power. The calculation assumed a 50-ohm load resistance seen by the In-phase and Quadrature (I,Q) detectors and did not include the waveguide loss between the antenna and the receiver.

Knowledge of the constant receiver gain is useful in that it allows calculation of the received power at the antenna, based on the recorded I,Q voltages and the recorded AGC attenuator settings for a particular range cell, the assumed 50-ohm resistance, the receiver noise power, and the waveguide loss.

The signal power received at the antenna may be calculated (in linear units) as

$$P_{Ant} = \left[\frac{P_{I,Q} \times AGC}{G} - N\right] \times L_{WG} \tag{1}$$

where P_{Ant} is power received at the antenna, $P_{I,Q}$ is the I,Q power calculated from the complex I,Q voltage magnitude squared and divided by 50 ohms, AGC is the total attenuation provided by the three AGC attenuators, G is the constant receiver gain, N is the receiver system noise power, and L_{WG} is the waveguide loss (approximately 1.38).

Receiver gain was calculated for both the wide bandwidth and narrow bandwidth Intermediate Frequency (IF) filter settings. As shown in figure 3 of [2], the wide IF bandwidth was 7 MHz, while the narrow IF bandwidth was 2 MHz [3].

C. Receiver Noise

The equivalent receiver system noise power was calculated as seen at the input to the receiver. The calculations incorporated I,Q voltages and AGC attenuation values recorded when the IFR input power to the receiver had been -127 dBmW, well below the expected receiver noise power. For each IF filter bandwidth, the noise power was found using the average gain calculated at that bandwidth, as described in part B above.

III. TABULATED RESULTS OF 1992 CALIBRATIONS

There are 10 pre-flight calibration data sets in mode 6. The transmitter power and receiver gain for those data sets are shown below in table 1.

Table 1. - TRANSMITTER POWER AND RECEIVER GAIN
R/T UNIT#2, MODE 6, PRE-FLIGHT

Flight Number	Date	Transmitter Power, watts		Receiver Gain, dB	
		Low	High	Wide IF Bandwidth	Narrow IF Bandwidth
Denver 11	7-15-92	178	*	123.2	121.7
Denver 12	7-16-92	180	1580	*	*
Denver 13	7-20-92	179	1645	122.8	121.4
Denver 15	7-22-92	200	1780	123.6	122.3
Denver 16	7-23-92	182	1783	123.1	121.7
Orlando 10	8-11-92	184	*	123.0	121.9
Orlando 11	8-12-92	186	*	123.0	121.8
Orlando 12	8-13-92	188	*	122.7	121.4
Orlando 15	8-17-92	190	*	123.1	121.9
Orlando 17	8-20-92	196	*	123.4	122.1
Averages		186	1697	123.1	121.8

* Data not available

Table 2 shows the receiver system noise averaged over all the days when mode 6 measurements were done.

Table 2. - AVERAGE RECEIVER NOISE, MODE 6

Wide IF Bandwidth	Narrow IF Bandwidth
-107.0 dBmW	-107.9 dBmW

Four calibration data sets allow calculation of the effective high power amplifier gain. The results are shown in table 3.

Table 3. - HIGH POWER AMPLIFIER GAIN, MODE 6

Flight Number	Low Power, watts	High Power, watts	Gain, dB
Denver 12	180	1580	9.43
Denver 13	179	1645	9.63
Denver 15	200	1780	9.49
Denver 16	182	1783	9.91
		Average	9.62

Four calibration data sets contain same-day measurements done in both mode 6 and mode 7. Table 4 shows a comparison of these mode 6 and mode 7 results, including receiver gain and receiver noise.

Table 4. - COMPARISON OF MODE 6 AND MODE 7: RECEIVER GAIN AND RECEIVER NOISE

Flight Number	Mode	Receiver Gain, dB		Receiver Noise, dBmW	
		Wide IF Bandwidth	Narrow IF Bandwidth	Wide IF Bandwidth	Narrow IF Bandwidth
Orlando 10	6	123.0	121.9	-106.8	*
	7	123.0	121.8	-109.1	*
Orlando 12	6	122.7	121.5	-107.2	*
	7	122.7	121.4	-109.6	-110.1
Orlando 15	6	123.1	121.9	-106.5	-107.8
	7	122.8	121.5	-109.4	-109.8
Orlando 17	6	123.4	122.1	-106.7	-107.2
	7	123.2	121.6	*	*

* Data not available

IV. RECEIVER GAIN FOR R/T #2 DURING YEARS 1991 AND 1992

Figure 1 is a plot of the pre-flight receiver gains for R/T unit #2 over a period including most of the Windshear experiment flights in 1991 and 1992.

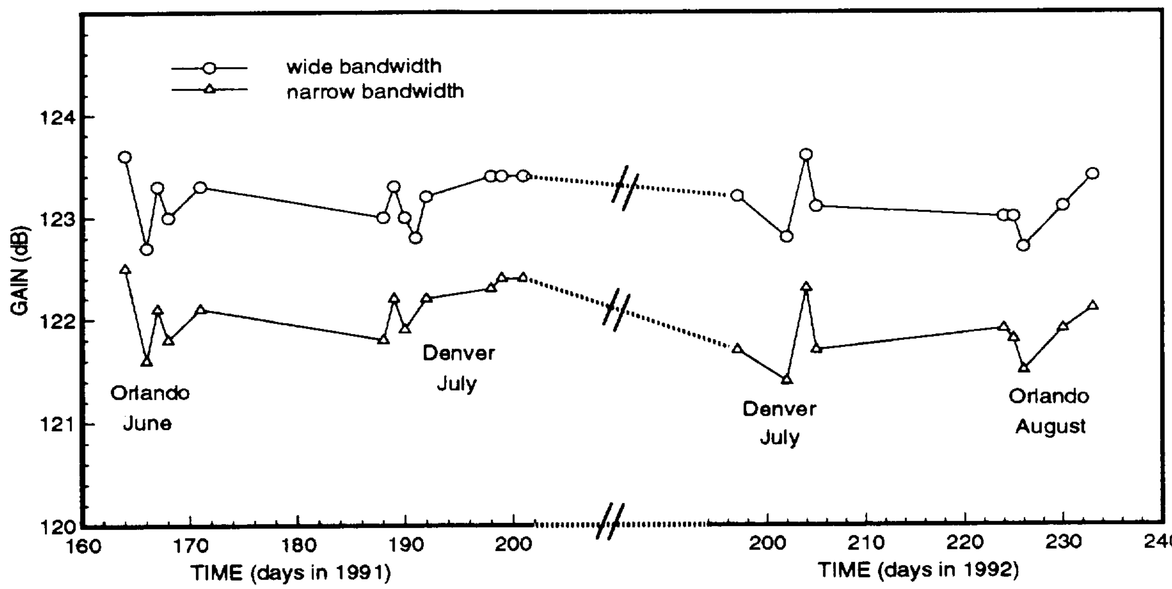

Figure 1. - Receiver gain for R/T #2, calculated from pre-flight calibration data in mode 6 over a 13-month period. The two plots show gains for wide and narrow IF bandwidths.

V. RESULT SUMMARY

A. Transmitter Power and Power Amplifier Gain

In mode 6, the radar mode most commonly used during the Windshear experiments, the average peak transmitter power was 186 watts, with a standard deviation of 7 watts. In mode 7, the peak transmitter power averaged 7 watts lower than in mode 6. The average effective high power amplifier gain was 9.62 dB, producing an expected 1704 watts peak power in the high power mode.

B. Receiver Gain

The average receiver gain was 123.1 dB for the wide IF bandwidth and 121.8 dB for the narrow IF bandwidth. These results agree with the results from the 1991 calibrations, where the narrow bandwidth produced one dB less gain than the wide bandwidth. The plots in figure 1 show very good gain stability for R/T #2 over the entire course of the Windshear experiments, each gain staying within a range of 0.9 dB.

There were no notable differences in receiver gain between mode 6 and mode 7 for a particular IF bandwidth.

C. Receiver Noise

The average receiver noise in mode 6 was -107.0 dBmW using the wide bandwidth IF filter and -107.9 dBmW using the narrow bandwidth IF filter. In mode 7, the receiver noise was lower, the averages being -109.4 dBmW, wide band, and -110.0 dBmW, narrow band. This slightly more than 2-dBmW lower receiver noise for mode 7 is reasonable, since mode 7 used a narrower bandwidth video (lowpass) filter, corresponding to the wider pulse width. The lowpass filters are pictured in figure 3 of [2].

Table 5. - Radar Parameters For Modes 6 and 7

Radar Parameter	Mode 6	Mode 7
PRF, Hz	3755	3755
Pulse Width, μs	0.96	1.92
Display Mode	WX [1]	WX
Display Gain, dB	32	32
Display Range, nmi	15	15
Antenna Polarization	HOR	HOR
Scan Angle, deg	0±30	0±30
Tilt Angle, deg	0±0	0±0
Window Delay Time, μs	5.76	7.68
Range Sampling [2]	0	0
Range Alias	OFF	OFF
Tape Speed, in/s	30	30
Antenna Scan Rate, deg/s	14.625	29.25
Number of Range Bins	91	91
Range Resolution, ft	472.1	944.2
Sampling Interval, ft	472.1	944.2
Window Delay Range, ft	2833	3777
Window Length, nmi	7.07	14.14
Alias Windspeed, kn	58.8	58.8
Antenna Scan Mode	AZ	AZ
Antenna Scan Time, s	4.1	2.1
Available Run Time, min	60	60

[1] Weather display mode

[2] The number of range bins skipped between recorded bins

REFERENCES

[1] IFR Inc., "Operation Manual: RDX/RDC-7708 Weather Radar Test Set," Appendix A: "Specifications," Wichita, Kansas, 1986, pp. A-1 through A-5.

[2] Mackenzie, Anne I., "Windshear Radar Calibration: Transmitter Power and Receiver Gain Stability," NASA TM 107589, June 1992.

[3] Schrader, James H., "Summary Description and Operating Characteristics of the Windshear Experimental Radar Data System," NASA CR 189731 (RTI/4500/002-02I, Research Triangle Institute, January 1991).

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13. ABSTRACT *(Maximum 200 words)*

During the 1992 NASA airborne Doppler windshear radar flights, radar calibrations were performed prior to each flight in order to determine transmitter power, receiver gain, and receiver noise power. The calibration results show that the average transmitter power in radar mode 6 was 186 watts, with a standard deviation of 7 watts. The average high power amplifier gain was 9.62 dB. At the wide IF bandwidth setting, the receiver gain was 123.1 dB, while at the narrow IF bandwidth setting, the gain was 121.8 dB. The receiver system noise as seen at the receiver input was -107.0 dBmw using the wide IF bandwidth and -107.9 dBmw using the narrow IF bandwidth. In radar mode 7, the receiver gain was the same as in mode 6. However, the receiver noise in mode 7 was about 2.5 dB less using the wide IF bandwidth and 2.0 dB less using the narrow IF bandwidth. The R/T unit flown in 1992 had also been flown the previous year when it produced comparable results. This technical memorandum was written as a follow-up to NASA TM-107589 (June 1992), which describes similar radar calibrations performed during the 1991 windshear radar flight experiments.

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