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CALIBRATION OF THE C.R.C. HIGH-FREQUENCY DIRECTION-FINDING RECEIVER SYSTEM AT OTTAWA

by

M.J. BURKE

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ABSTRACT

Calibration of the C.R.C. high-frequency direction-finding receiver system is discussed. It is shown that errors in gain should be less than 1 dB and errors in phase should be less than 2°. The system is also shown to be highly stable over several days.

1. INTRODUCTION

The High-Frequency Direction-Finding (HFDF) equipment[1] includes a number of aerials in two arrays at right angles. Each aerial is connected to its own receiver. In use, the in-phase and quadrature components of signal level are recorded from each receiver. The components are subsequently analyzed for gain and phase, where the phase is taken relative to that of the last receiver (#90) which serves as a phase reference. From the set of phases it is possible to find the azimuth and elevation of an incoming signal.

As practised prior to this work, during recording, the receivers were either set on fixed gain, or uncalibrated Automatic Gain Control (AGC) was used. In the former case, this had the disadvantage that, at times, the receivers could be overloaded or the signal was not detectable. In the latter case, with uncalibrated AGC on each receiver channel, the receiver gains were, in general, not equal and amplitude information was lost. These disadvantages are virtually eliminated if the receivers are run with AGC and the AGC voltages are recorded. However, in this case, it is necessary to calibrate the equipment for all possible signal levels and required frequencies. In this Note, a method of calibration is described and the stability of the equipment investigated.

2. METHOD OF CALIBRATION

During calibration, the equipment is under the control of a program running in a Honeywell 516 computer. At the start of calibration, various parameters are entered via the keyboard on request from the program. These parameters include the number of receivers to be tested, the range of attenuation levels required and the various frequencies to be used during the test. For the work reported here the input signal levels varied from -35 dBm to -131 dBm in 6 dB steps (the reference level is 1 mW into 50 ohms). The frequencies used varied from 8 to 16 MHz in 2 MHz steps. For these values it takes about 10 minutes to record the calibration data for 58 receivers, in this case receivers #33 to #90.

During calibration the in-phase and quadrature signals from the receivers and the AGC voltage are recorded and stored on magnetic tape. Subsequently, these data are analyzed on a Sigma 9 computer and the gain, phase and AGC for each receiver for each attenuation level and frequency is listed. The same information is also written on a magnetic disc file for further investigations, or used by other programs to correct the gain and phase during data analysis.

3. GAIN

The gain data for a particular run for Receiver 33 are shown in Table 1. For a frequency of 8 MHz, the table shows receiver gain in dB for a series of calibration-signal levels. For the other frequencies, differences with respect to the 8 MHz gain are shown. It will be noted from Table 1 that, relative to the gain at frequency 8.0 MHz, the gains at other frequencies decrease with decreasing calibration-signal level and that, for a given input level, this decrease in gain is relatively constant from 12.0 to 16.0 MHz. Subsequently, it was found that much of this change of gain with frequency was due to the non-flatness of the calibration-signal level as a function of frequency. For calibration purposes it will be necessary to derive a set of gains as a function of calibration-signal level for at least one frequency. If the defects in the signal generator cannot be corrected then it will be necessary to repeat this set at other frequencies, where the number of sets will depend upon the accuracy required.

The values of gain for Receiver 34 are shown in Table 2. The variation of gain with frequency and calibration-signal level for this receiver is similar to that for Receiver 33. The other receivers also exhibited similar characteristics so their values of gain are not presented in this Note.

4. PHASE

Receiver 33 phase results are shown in Table 3. The values of phase for other than 8 MHz are the differences of the phases with respect to the values of phase at 8 MHz. Also included in the table are the mean and r.m.s. deviation of the phases.

TABLE 1

Receiver 33, day 335, 1975. Gain in dB, as a function of frequency and calibration-signal level. For frequencies 10.0 to 16.0 MHz the values are for the gains at these frequencies less the corresponding gains at 8.0 MHz.

	Frequency MHz				
	8.0	10.0	12.0	14.0	16.0
Calibration-Signal Level dBm	**Gain (dB)**			**Difference (dB)**	
-35	56	-0.0	-0.1	-0.1	-0.1
-41	62	-0.0	-0.1	-0.1	-0.1
-47	67	-0.1	-0.1	-0.2	-0.1
-53	73	-0.1	-0.1	-0.2	-0.1
-59	79	-0.1	-0.1	-0.2	-0.1
-65	84	-0.1	-0.1	-0.2	-0.1
-71	90	-0.1	-0.2	-0.2	-0.1
-77	95	-0.1	-0.2	-0.2	-0.2
-83	100	-0.1	-0.2	-0.2	-0.2
-89	105	-0.1	-0.3	-0.3	-0.2
-95	110	-0.1	-0.3	-0.3	-0.3
-101	115	-0.1	-0.3	-0.4	-0.3
-107	119	-0.2	-0.4	-0.5	-0.4
-113	123	-0.2	-0.5	-0.5	-0.5
-119	127	-0.2	-0.5	-0.6	-0.5
-125	130	-0.4	-0.6	-0.7	-0.7
-131	131	-0.3	-0.6	-0.7	-0.8

TABLE 2

Receiver 34, day 335, 1975. Gain in dB, as a function of frequency and calibration-signal level. For frequencies 10.0 to 16.0 MHz the values are for the gains at these frequencies less the corresponding gains at 8.0 MHz.

	Frequency MHz				
	8.0	10.0	12.0	14.0	16.0
Calibration-Signal Level dBm	**Gain (dB)**			**Difference (dB)**	
-35	60	-0.1	-0.2	-0.3	-0.2
-41	66	-0.1	-0.2	-0.3	-0.2
-47	71	-0.1	-0.2	-0.3	-0.2
-53	76	-0.1	-0.2	-0.3	-0.2
-59	81	-0.1	-0.3	-0.3	-0.3
-65	87	-0.1	-0.3	-0.3	-0.3
-71	92	-0.1	-0.3	-0.3	-0.3
-77	96	-0.1	-0.3	-0.4	-0.4
-83	101	-0.1	-0.3	-0.4	-0.3
-89	106	-0.2	-0.4	-0.4	-0.4
-95	110	-0.2	-0.4	-0.5	-0.4
-101	114	-0.2	-0.5	-0.6	-0.5
-107	118	-0.3	-0.6	-0.7	-0.6
-113	121	-0.3	-0.7	-0.8	-0.8
-119	123	-0.4	-0.8	-0.9	-0.8
-125	124	-0.5	-1.0	-1.3	-1.0
-131	125	-0.3	-0.8	-1.1	-1.5

TABLE 3

Receiver 33, day 335, 1975. Phase as a function of frequency and calibration-signal level. For frequencies 10.0 to 16.0 MHz the values are for the phases at these frequencies less the corresponding phases at 8.0 MHz.

	Frequency MHz				
	8.0	10.0	12.0	14.0	16.0
Calibration-Signal Level dBm	Phase (Deg)		Difference (Deg)		
-35	-137.3	2.7	8.3	8.7	6.9
-41	-123.5	0.3	1.3	0.3	0.6
-47	-125.0	-0.2	0.3	-0.7	-0.2
-53	-128.0	0.1	0.9	0.0	0.3
-59	-128.1	0.3	1.3	0.4	0.6
-65	-127.6	0.3	1.2	0.4	0.6
-71	-127.3	0.2	1.2	0.4	0.6
-77	-127.3	0.2	1.2	0.3	0.6
-83	-127.4	0.2	1.0	0.1	0.5
-89	-127.7	0.2	1.1	0.2	0.6
-95	-128.1	0.1	1.0	0.2	0.7
-101	-128.5	0.2	0.9	0.1	0.6
-107	-128.8	0.1	1.0	0.0	0.5
-113	-129.0	0.1	0.9	0.1	0.1
-119	-129.3	0.1	-0.4	-0.2	-0.6
-125	-130.9	1.8	2.0	1.8	-0.6
-131	-129.5	3.1	-0.9	-1.8	0.0
MEAN	-128.4	.6	1.3	0.6	0.7
RMS	2.8	1.0	1.9	2.1	1.6

TABLE 4

Receiver 34, day 335, 1975. Phase as a function of frequency and calibration-signal level. For frequencies 10.0 to 16.0 MHz the values are for the phases at these frequencies less the corresponding phases at 8.0 MHz.

	Frequency MHz				
	8.0	10.0	12.0	14.0	16.0
Calibration-Signal Level dBm	Phase (Deg)		Difference (Deg)		
-35	136.3	-0.7	1.0	0.4	-0.2
-41	136.9	-0.7	1.9	0.2	-0.3
-47	137.1	-0.8	1.8	0.2	-0.3
-53	137.2	-0.8	1.7	0.1	-0.4
-59	137.1	-0.8	1.8	0.1	-0.4
-65	136.9	-0.8	1.7	0.4	-0.4
-71	136.7	-0.8	1.7	0.0	-0.4
-77	136.3	-0.8	1.7	0.0	-0.4
-83	135.8	-0.8	1.6	-0.1	-0.5
-89	135.2	-0.8	1.7	0.4	-0.4
-95	134.6	-0.8	1.6	0.0	-0.4
-101	133.8	-0.8	1.6	0.1	-0.3
-107	133.1	-0.8	1.6	0.1	-0.3
-113	132.1	-0.6	1.4	0.8	0.0
-119	131.5	-0.7	-0.3	0.8	0.1
-125	129.7	1.9	1.2	2.0	-0.4
-131	131.6	2.6	-1.6	-1.9	-1.2
MEAN	134.8	-0.4	0.5	0.2	-0.4
RMS	2.3	1.0	0.6	0.7	0.2

The phases at -35 dBm calibration-signal level depart by several degrees from the mean. This departure is attributed to near-saturation of the receiver and, for this reason, it is recommended that this level not be used in practice. As shown in Table 4 for Receiver 34, saturation does not occur for all receivers. Overall, about 10 receivers show the saturation effect indicated in Table 3.

In deriving a value of phase for analyzing data an average is taken over the 15 values from -41 dBm to -125 dBm, for the frequency chosen. With this average value the rms deviation in phase should not be greater than 2° and is relatively independent of frequency.

5. AUTOMATIC GAIN CONTROL (AGC)

Receiver 33 AGC voltages are shown in Table 5. The values for 10 to 16 MHz are percentage differences relative to the voltages of 8 MHz. As can be seen from this table, for a given calibration-signal level, the values for frequencies 12.0 to 16.0 MHz are relatively independent of frequency. Similar results are shown for Receiver 34 in Table 6. The variation in the percentage departures shown in this table are about the worst noted for the 58 receivers examined.

The variation of the gain of a receiver as function of AGC voltage is dependent on the component values used in constructing the receiver and will vary from receiver to receiver, as shown in Figures 1 and 2 for Receivers 33 and 34. Even if a suitable mathematical expression could be fitted to these curves, this expression would change from receiver to receiver. It was for this reason that it was decided that the simplest way to calibrate each receiver, was to read in a table of gain versus AGC voltage for that receiver for each of the 17 calibration-signal levels, and use interpolation during analysis. As mentioned earlier only one value of phase, the mean value, is used for each receiver.

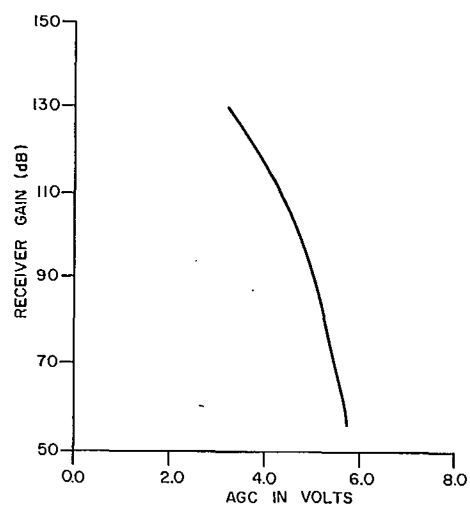

Figure 1. Receiver Gain in dB as a Function of AGC Voltage for Receiver 33 at 12 MHz, Day 335, 1975

TABLE 5

Receiver 33, day 335, 1975. AGC voltages as a function of frequency and calibration-signal level. For frequencies 10.0 to 16.0 MHz the values are for the AGC voltages at these frequencies less the corresponding voltages at 8.0 MHz expressed as a percent difference.

	Frequency MHz				
	8.0	**10.0**	**12.0**	**14.0**	**16.0**
Calibration-Signal Level dBm	**AGC (V)**		**% Difference (V)**		
-35	5.758	-.2	-.4	-.5	-.3
-41	5.680	-.2	-.3	-.4	-.3
-47	5.574	-.2	-.5	-.6	-.5
-53	5.458	-.3	-.6	-.7	-.5
-59	5.333	-.2	-.5	-.6	-.4
-65	5.214	-.3	-.6	-.7	-.5
-71	5.084	-.3	-.7	-.8	-.6
-77	4.938	-.4	-.8	-.9	-.8
-83	4.768	-.4	-.9	-1.0	-.9
-89	4.580	-.5	-1.1	-1.2	-1.0
-95	4.377	-.5	-1.2	-1.4	-1.1
-101	4.159	-.6	-1.4	-1.5	-1.3
-107	3.936	-.7	-1.4	-1.6	-1.3
-113	3.712	-.6	-1.3	-1.6	-1.3
-119	3.503	-.6	-1.3	-1.5	-1.3
-125	3.321	-.5	-1.1	-1.2	-1.1
-131	3.173	-.2	-.7	-.9	-.8

TABLE 6

Receiver 34, day 335, 1975. AGC voltages as a function of frequency and calibration-signal level. For frequencies 10.0 to 16.0 MHz the values are for the AGC voltages at these frequencies less the corresponding voltages at 8.0 MHz expressed as a percent difference.

	Frequency MHz				
	8.0	**10.0**	**12.0**	**14.0**	**16.0**
Calibration-Signal Level dBm	**AGC (V)**		**% Difference (V)**		
-35	6.581	-.3	-1.0	-1.3	-1.0
-41	6.290	-.5	-1.2	-1.4	-1.2
-47	5.982	-.6	-1.3	-1.5	-1.3
-53	5.659	-.6	-1.5	-1.7	-1.5
-59	5.322	-.7	-1.6	-1.8	-1.6
-65	4.982	-.8	-1.7	-2.0	-1.7
-71	4.638	-.8	-1.8	-2.2	-1.8
-77	4.296	-.9	-2.0	-2.3	-2.0
-83	3.953	-.9	-2.1	-2.5	-2.1
-89	3.619	-.9	-2.3	-2.7	-2.3
-95	3.296	-1.1	-2.5	-2.8	-2.5
-101	2.976	-1.2	-2.6	-2.9	-2.6
-107	2.676	-1.1	-2.7	-3.1	-2.7
-113	2.403	-1.0	-2.4	-2.6	-2.4
-119	2.180	-1.1	-2.2	-2.5	-2.3
-125	2.016	-.7	-1.5	-2.0	-1.7
-131	1.909	-.2	-.9	-1.0	-1.2

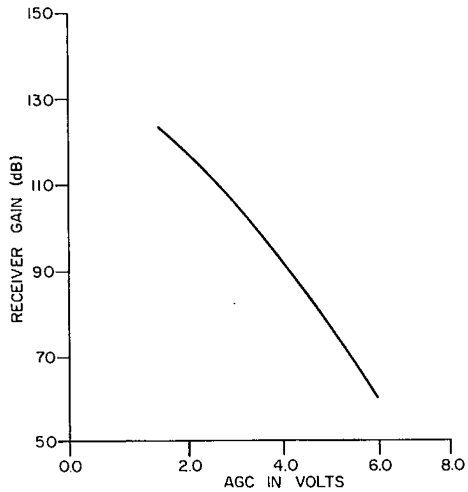

Figure 2. Receiver Gain in dB as a Function of AGC Voltage for Receiver 34 at 12 MHz, Day 335, 1975

6. LONG-TERM STABILITY

To check the stability of the equipment, nine calibration runs were taken over five consecutive days. An examination of the data showed that, over this period of time, there was little change in the values of gain and phase. Typical variations are shown for Receivers 33 and 34 in Tables 7 and 8. The values shown are for the deviations about the means over the 5 days. The rms deviation is also included. The day and time of each calibration are shown in the Tables. The gain measurements are in dB.

Both Receivers 33 and 34 can be regarded as representative of the best case. An example of the worst case is represented by the results for Receiver 41 also included in the two Tables. For this receiver, as shown by an * in Table 8, the phase changed by more than 2° between calibration runs for 3 of the 9 observations. However, these changes are not reflected in the gain deviation which remained relatively constant over the period, at least to the same degree as that for Receivers 33 and 34.

Of the 58 receivers, over the 5 days, only 16 showed a phase change of more than 2° and, of these 16 receivers, 12 showed only 1 such change, 2 showed 2 and 2 showed 3.

It is concluded that over a 5 day period, any variation in gain and phase of the receivers is within experimental limits. However, it is recommended that calibration runs be taken twice a day primarily as a check on the equipment. Any receiver malfunction should be indicated by anomalous calibration values.

TABLE 7

Gain deviation (dB) about the mean over a five day period, recorded at 14.0 MHz and a calibration-signal level of -89 dBm.

DAY	329	330	330	331	331	332	332	333	333	
TIME	2257	1001	2244	0956	2343	0959	2244	1212	2251	
RECEIVER				GAIN DEVIATION (dB)						R.M.S.
33	0.02	-0.15	-0.12	-0.16	-0.53	-0.10	0.21	0.28	0.52	0.29
34	0.00	-0.15	-0.09	-0.14	-0.39	-1.13	0.20	0.28	0.43	0.24
41	-0.07	-0.34	-0.26	0.06	-0.46	0.09	0.40	0.17	0.43	0.30

TABLE 8

Phase deviation (degrees) about the mean over a five day period, recorded at 14.0 MHz and a calibration-signal level of -89 dBm.

DAY	329	330	330	331	331	332	332	333	333	
TIME	2257	1001	2244	0956	2343	0959	2244	1212	2251	
RECEIVER				PHASE DEVIATION						R.M.S.
33	-1.02	-1.02	-0.62	-0.52	0.18	0.38	1.28	0.28	1.08	0.81
34	-1.49	-1.09	-0.59	-0.39	0.91	0.71	0.91	0.31	0.71	0.86
41	-1.16	-0.96	0.24	-2.36*	1.74*	1.34	-0.76*	1.04	0.84	1.29

7. CONCLUSIONS

It has been shown that, if the receiver system is run under AGC, the errors in gain should be less than 1 dB and the errors in phase should be less than 2°. The variations in AGC voltage as a function of calibration-signal levels have been found to differ from receiver to receiver because they are dependent upon the receiver components. For this reason, it is recommended that, for each receiver, a set of gains, phases and AGC voltages be derived for calibration-signal levels ranging from -41 dBm to -131 dBm in 6 dB steps for at least one frequency and interpolation be used during data analysis. Because of slight changes of the three parameters with frequency, it may be necessary to repeat this set at other frequencies where the number of sets will depend upon the accuracy required.

It was also shown that the system remained stable within experimental limits over a period of at least 5 days. This stability can be put to advantage as a means of detecting any malfunctions in the system. If calibration runs are taken twice a day, any abnormalities in the calibration results will be readily detected and can be used to pin-point that part of the system which is at fault.

8. REFERENCES

1. Rice, D.W. and E.L. Winacott. *A Sampling Array for HF Direction-Finding Research*. CRC Report No. 1310, November 1977.

CRC DOCUMENT CONTROL DATA

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8. ABSTRACT:

Calibration of the C.R.C. high-frequency direction-finding receiver system is discussed. It is shown that errors in gain should be less than 1 dB and errors in phase should be less than 2°. The system is also shown to be highly stable over several days.

9. CITATION:

Government of Canada Gouvernement du Canada