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AN ASSESSMENT OF THE INFORMATION RECOVERED FROM THE SATELLITE WRESAT

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AN ASSESSMENT OF THE INFORMATION RECOVERED FROM THE SATELLITE WRESAT

A.P. Clarke

S U M M A R Y

This paper briefly outlines the transmission, recording and processing of the information telemetred from the satellite WRESAT. An assessment is then made of the quantity and quality of the information recovered from the records.

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1. INTRODUCTION

The purpose of this paper is to present an assessment of the amount and quality of the information recovered from the satellite WRESAT. In order to present a complete picture, the transmission format and recording, the analogue-to-digital conversion, and the computer method used to demultiplex the data from the A/D conversion, will be broadly outlined. The method of assessment will be indicated and tabulated assessments of the results presented. The recovery of further information will be discussed briefly.

A detailed analysis and description of the analogue-to-digital conversion and the computer processing program is available in reference 1.

2. THE TELEMETRY TRANSMISSION FORMAT

The telemetry transmitter operated at 256 channels per second. Pulses obtained from a switch sampling the output from transducers at the various experiments were used to frequency-modulate a subcarrier over a nominal range of 4.5 kHz to 15 kHz. The frequency modulated subcarrier was then used to phase modulate an RF carrier for transmission.

Figure 1 shows the telemetry sampling format. The frames are sampled in sequence and in each frame the channels are sampled in sequence. In the figure, the blank squares representing the experiments are not detailed as they do not directly concern this paper. The channels marked S are channels that are nominally constant in value at -0.25 volts. The square marked CLOCK is a channel allocated to recording a coded form of an on-board clock. The voltage range shown corresponds approximately with the full deviation of the frequency modulation. This sequential sampling is referred to as time-division multiplexing.

3. RECORDING OF THE TRANSMITTED SIGNAL

The information was recorded as time-division multiplexed frequency modulated signals in the range 4.5 kHz to 15 kHz on magnetic tapes at various tracking stations.

Table 1 gives a list of these stations. There are 3 groups:

(1) The stations of the STADAN network.

(2) The French stations, situated mainly in Africa.

(3) A group of miscellaneous stations, which includes Woomera.

Stations in groups 1 and 3 recorded the frequency modulated signal at 15 inches per second, and the French stations recorded it at half this speed. Stations in group 1 also recorded station time as a 1-second binary code in the form of amplitude modulation of a carrier on another tape track separate from the data track.

4. CONVERSION OF THE ANALOGUE SIGNAL TO DIGITAL FORM

Before digital processing could take place, analogue to digital conversion was necessary. A schematic of the conversion equipment is shown in figure 2. In order to maintain compatibility with this equipment, tapes from stations in

group 1 and group 3 were played back to this equipment at 60 inches per second. Tapes from the French stations were played back at 30 inches per second. This ratio of replay speed to recording speed gave a nominal input data bandwidth to the conversion equipment of 20 kHz to 60 kHz.

A pulse-averaging discriminator was used to convert the frequency modulated signal to a D.C. output proportional to frequency. The discriminator includes an input filter with a pass-band of 15 kHz to 65 kHz, hence a substantial portion of the discriminator range was used. The discriminator terminates with a low-pass filter of bandwidth of 7.2 kHz.

The effect of the discriminator is to recover a scaled form of the pulse-amplitude modulation which is generally referred to as a voltage histogram. The voltage histogram is sampled at a constant rate averaging 3.9 samples per channel. Each sample is digitised to form a 10-bit binary word, where a word consisting of ten '1s' corresponds with 65 kHz and ten '0s' corresponds with 15 kHz. An 11th bit, which can be obtained from sampling the amplitude modulation of the timing code at the instant of sampling the voltage histogram, is added to each word. The complete 11 bit words are written onto digital tapes in a form suitable for input to the WRE IBM 7090 computer.

5. COMPUTER PROCESSING

Reference can be made again to figure 1. Synchronisation of each cycle of 8 frames is obtained by identifying in the computer the repetition of the pattern of frame 7, channels 1, 2 and 3, i.e., the cycle synchronisation pattern is the stepped voltages 5 volts, 3.9 volts and 1.25 volts. After the identification of each pair of synchronisation patterns, channel extraction is performed in the computer by taking the data samples between two cycle synchronisation patterns and dividing the samples among 128 equal intervals of time. Since the mean number of samples per channel is 3.9, each channel interval will contain 3 or 4 samples. An estimate of the channel value is then made from the last 2 or 3 samples in each channel interval. The estimates are in terms of the discriminator output voltage.

Calibrations are now applied in two stages to each channel value. In the first stage, the channel values in discriminator volts are transformed to satellite volts by using the monitored values of the 0 volt and 5 volt calibration channels. This eliminates any drifts in frequency that may have occurred. In the second stage, the channel satellite voltage values are transformed to experimental units by applying calibration tables of volts against experimental units obtained from laboratory measurements. After the data calibration, the satellite clock time is decoded if a complete code read-out has occurred.

The calibrated channel values are tabulated and also written onto magnetic tapes, which are available for further computer analysis.

6. QUANTITY OF DATA RECOVERED

Difficulties in data processing arose with some passes in that the recorded signal fluctuated through the threshold of the WRE analogue to digital conversion equipment. This was due to compounding the effect of the rotation of the satellite and its aerials with the attenuation of the signal because of long slant ranges and low incidence angles. The deficiency was 2 to 3 dB's.

At some slant ranges and incidence angles some stations were unable to record a signal sufficiently high to meet the threshold of the WRE analogue to digital conversion equipment. The signal loss varied from 10 to 30 dB's.

The station passes have been categorised into 3 broad classes:

processable

marginal

unprocessable

It is emphasised that the "marginal" and "unprocessable" categories are with respect to the WRE analogue-to-digital conversion equipment only.

The performance of the stations in the various groups is shown in Table 2 for the total processing load of 221 passes. Table 2 is summarised in Table 3.

7. QUALITY OF DATA PRODUCED

Error estimates have been made on the published data. It would appear that the data have RMS errors of 0.2% to 1% of the data range of 0 volts to 5 volts. This range of values was obtained from forming spectral estimates of the voltage values of a number of the channels. The error estimates are certainly well within the original specification of 1% of the full-scale deviation of the subcarrier for errors generated by transmission, reduction and calibration.

8. CONCLUSION

A number of points should be made in concluding this paper.

First, it would appear that the transmitter and data reduction system performed satisfactorily.

Secondly, a number of experiments used logarithmic amplifiers together with only a small fraction of the range of the deviation of the subcarrier. This has apparently hampered analysis.

Finally, it is possible that further information can be obtained from the recorded data with minor development in the equipment and/or technique.

Variations of equipment and refinements to the computer program have been considered, with the aim of improving on the threshold of the conversion equipment and so recovering the information on the marginal tapes. Methods contemplated include measurement in the computer of the subcarrier signal frequency. This is a technique which has recently proved feasible. One possible procedure is described in reference 2.

Other ideas have involved various manipulations of the filters at the discrimination stage of the analogue-to-digital conversion procedure.

However, any further processing depends on what can be considered of sufficient scientific interest to warrant the effort involved. It is certainly true that a substantial portion of the data currently considered marginal could be processed with some development in the analogue and computer techniques.

REFERENCES

1. A.P. Clarke and W.R. Anthoney - A data-handling system for information telemetred from the satellite WRESAT - Electrical Engineering Transactions of the Institution of Engineers, Australia. September, 1970.

2. A.P. Clarke and H.H. Evans - Demodulation of FM signals using a digital computer - Proceedings of the fourth Australian Computer Conference, 1969.

TABLE 1. TRACKING STATIONS

GROUP 1	GROUP 2	GROUP 3
FAIRBANKS, ALASKA	BZN097	BLOSSOM POINT, MARYLAND
FORT MYERS, FLORIDA	BTY	COOBEY CREEK, QUEENSLAND
KAUAI, HAWAII	CNA093	WOOMERA, SOUTH AUSTRALIA
JOHANNESBURG, SOUTH AFRICA	PRETORIA, AFRICA	LASHAM, ENGLAND
TANANARIVE, REP. OF MALAGASY	096	
ST. JOHNS, NEWFOUNDLAND		
ORRORAL VALLEY, AUSTRALIAN CAPITAL TERRITORY		
QUITO, ECUADOR		
ROSMAN, NORTH CAROLINA		
SANTIAGO, CHILE		
LIMA, PERU		
SOLANT, FALKLAND ISLANDS		
WINKFIELD, ENGLAND		
CARNARVON, WESTERN AUSTRALIA		

TABLE 2. TRACKING STATION PERFORMANCE

STATION	PASS	START TAPE (HRS)	STOP TAPE (HRS)	SECONDS OF DATA PUBLISHED
CARNARVON	1	06.29	06.37	265
	2	06.29	06.37	130
	8	17.24	17.40	181
	9	19.01	19.21	300
	23	18.06	18.25	345
	24	19.46	20.03	240
	30	06.18	06.24	194
	37	17.09	17.27	50
	38	18.45	19.05	253
	52	17.40	18.03	50
	53	19.24	19.42	60
	59	05.53	05.58	-
ALASKA	1	05.15	05.29	-
	2	06.57	07.13	354
	3	08.37	08.55	770
	4	10.19	10.37	195
	5	11.59	12.16	179
	6	13.38	13.55	601
	12	23.21	23.32	65
	13	01.00	01.12	627
	14	02.39	02.52	607
	15	04.22	04.33	361
	16	06.04	06.17	444
	17	07.44	07.59	458
	18	09.26	09.42	582
	19	11.05	11.21	680
	20	12.43	13.00	618
	21	14.23	14.37	482
	26	22.24	22.35	125
	27	00.03	00.15	524
	28	01.41	01.55	612
	29	03.24	03.35	119
	30	05.05	05.16	200
	31	06.46	07.00	159
	32	08.27	08.42	-
	33	10.06	10.24	440
	34	11.46	12.03	459
	35	13.26	13.40	248
	41	23.05	23.16	218
	42	00.41	00.55	630
	43	02.22	02.35	626
	44	04.04	04.15	470
	45	05.46	05.58	390
	46	07.27	07.41	415
	47	09.06	09.22	743
	48	10.56	11.02	685
	49	12.24	12.40	522
	50	14.03	14.17	276

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Table 2

STATION	PASS	START TAPE (HRS)	STOP TAPE (HRS)	SECONDS OF DATA PUBLISHED
ALASKA	55	22.02	22.14	432
	56	23.40	23.53	596
	57	01.18	01.33	657
	58	02.59	03.12	610
	59	04.41	04.56	530
BLOSSOM POINT	15	04.02	04.46	-
	24	19.02	19.11	-
	25	20.43	20.48	-
	39	19.41	19.52	-
	44	04.23	04.33	-
COOBY CREEK	1	04.55	-	-
	7	16.02	-	-
	8	17.40	-	-
FORT MYERS	17	07.54	08.17	409
	24	18.54	19.08	512
JOHANNESBURG	12	00.03	00.17	400
	13	01.41	01.55	715
	19	12.10	12.18	249
	27	00.42	00.59	598
	41	23.42	00.00	675
	42	01.23	01.38	682
	48	11.52	11.59	140
	55	22.42	22.56	742
	56	00.17	00.37	771
KAUAI	5	12.11	12.15	-
	6	13.55	14.13	-
	13	00.48	01.00	30
	19	11.16	11.35	-
	20	12.53	13.15	-
	28	01.33	01.42	-
	34	11.57	12.18	-
	35	13.38	13.55	-
	42	00.33	00.43	-
	48	10.56	11.16	-
	49	12.34	12.56	-
	57	01.09	01.20	-
LASHAM	6	13.26	-	-
	7	15.02	15.15	61
	21	14.09	14.19	-
	35	13.12	13.20	-
	36	14.49	15.01	61
	51	15.26	15.38	-
LIMA	1	06.49	07.02	-
	2	07.24	07.43	38

STATION	PASS	START TAPE (HRS)	STOP TAPE (HRS)	SECONDS OF DATA PUBLISHED
LIMA	17	08.10	08.27	744
	23	18.49	18.56	77
	30	05.37	05.49	-
	31	07.13	07.30	-
	46	07.50	08.08	68
TANANARIVE	11	22.17	22.36	313
	18	10.32	10.41	96
	25	21.24	21.38	201
	26	23.00	23.19	429
	40	22.02	22.22	256
	47	10.15	10.22	290
NEWFOUNDLAND	1	05.25	05.48	398
	8	16.45	16.55	-
	9	18.23	18.35	138
	15	04.32	04.54	222
	16	06.10	06.32	198
	23	17.24	17.37	350
	24	19.03	19.16	393
	29	03.34	03.56	281
	30	05.13	05.36	131
	37	16.26	16.38	30
	38	18.03	18.18	157
	44	04.15	04.36	-
	45	05.54	06.14	-
	52	17.02	17.17	160
	53	18.41	18.55	302
ORORAL	7	15.46	16.05	390
	8	17.24	17.44	778
	14	03.50	04.03	250
	21	14.54	15.11	560
	22	16.29	16.50	680
	36	15.33	15.51	673
	43	03.32	03.44	241
	50	14.34	14.48	507
	51	16.10	16.27	744
PRETORIA	4	11.28	11.33	-
	11	22.26	22.33	-
	12	23.59	00.17	-
	13	01.41	01.55	-
	26	23.06	23.16	-
	41	23.44	23.54	290
CNA093	8	16.42	16.46	-
	22	-	-	-
	51	15.20	15.30	350

STATION	PASS	START TAPE (HRS)	STOP TAPE (HRS)	SECONDS OF DATA PUBLISHED
BTY	6	13.24	13.35	-
	7	15.03	15.15	-
	8	16.46	16.53	-
	11	-	-	-
	12	23.36	23.53	-
	21	14.07	14.19	-
	36	14.50	15.00	-
	50	13.49	13.59	-
096	6	14.55	15.02	178
	12	23.53	00.00	-
	13	01.27	01.46	-
	14	03.06	03.18	-
	20	14.00	14.07	133
	42	01.11	01.28	-
BZN097	5	13.12	13.18	-
	12	23.53	00.11	-
	13	01.32	01.50	-
	19	12.17	12.21	-
	27	00.35	00.54	-
QUITO	2	02.71	07.40	400
	9	19.47	19.56	358
	16	06.25	06.46	867
	38	19.33	19.40	96
	45	06.10	06.27	794
	52	18.32	18.38	292
ROSMAN	1	05.30	05.47	58
	2	07.11	07.29	376
	3	08.51	09.07	117
	25	20.39	20.49	487
	31	06.38	07.18	385
	32	08.38	08.54	315
	39	19.40	19.51	588
	46	07.37	07.55	628
	54	20.17	20.28	541
	59	04.56	05.11	735
SANTIAGO	2	07.31	07.49	530
	8	17.58	18.07	200
	23	18.43	18.51	236
	37	17.45	17.53	140
	46	08.00	08.14	750
	52	18.23	18.30	90
	59	05.18	05.31	490
SOLANT	1	05.55	06.18	300
	2	07.36	07.55	545
	22	16.57	17.16	-
	30	05.43	06.04	130

STATION	PASS	START TAPE (HRS)	STOP TAPE (HRS)	SECONDS OF DATA PUBLISHED
SOLANT	31	07.25	07.43	130
	37	17.41	17.50	248
	44	04.47	05.01	481
	45	06.24	06.41	316
	51	16.39	16.47	60
WINKFIELD	6	13.23	13.57	503
	7	15.03	15.17	680
	12	23.31	23.54	410
	13	01.12	01.34	304
	14	02.53	03.13	729
	21	14.02	14.29	362
	22	15.42	16.00	582
	26	22.37	22.54	404
	27	00.18	00.37	260
	28	01.54	02.17	80
	35	13.11	13.22	597
	36	14.45	15.03	415
	41	23.16	23.37	609
	42	00.55	01.18	189
	43	02.34	02.56	759
	50	13.45	14.02	749
	51	15.27	15.41	540
	56	23.45	00.15	906
	57	01.33	01.54	607
	58	03.12	03.30	541
WOOMERA	1	-	-	80
	8	17.24	17.47	722
	9	19.10	19.20	-
	14	03.58	04.01	-
	29	04.37	04.45	40
	36	15.34	15.46	-
	37	17.11	17.27	226
	38	18.55	19.04	290
	43	03.39	03.43	30
	44	05.19	05.22	40
	51	16.10	16.26	220
	52	17.50	18.04	630
	58	04.15	04.21	-

TABLE 3. SUMMARY OF TABLE 2

STATION GROUP	NUMBER OF PASSES		
	PROCESSABLE	MARGINAL	UNPROCESSABLE
GROUP 1	145	5	15
GROUP 2	4	4	20
GROUP 3	16	11	1

PRIMARY CHANNEL NUMBER

FRAME NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	S	S	S	S												
2	5V	0V														
3	5V	CLOCK														
4	5V	0V														
5	0V															
6	0V	5V														
7	5V	3.9V	1.25V													
8	0V	5V														

FIGURE 1. THE TELEMETRY TRANSMISSION FORMAT

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Figure 1

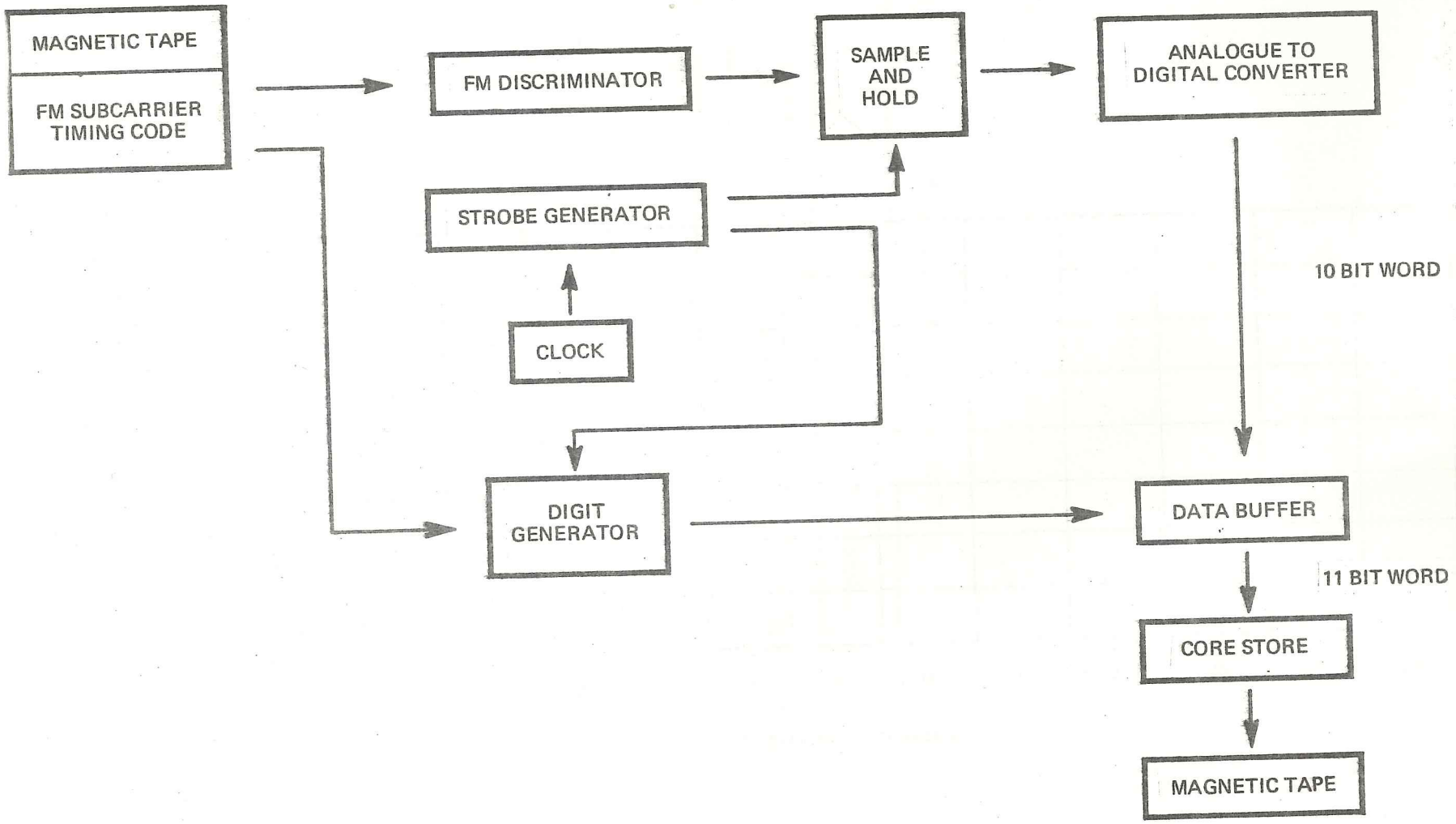

FIGURE 2. DATA CONVERSION SYSTEM

DOCUMENT-CONTROL DATA

1. Security Classification: (a) Complete document: Unclassified (b) Title in isolation: Unclassified (c) Summary in isolation: Unclassified	2. Establishment, Document, Type, Number, Wing WRE-TN-516-(T) 3. Document Date October, 1971

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7. Summary

This paper briefly outlines the transmission, recording and processing of the information telemetred from the satellite WRESAT. An assessment is then made of the quantity and quality of the information recovered from the records.

8. Descriptors WRESAT ARTIFICIAL SATELLITES TELEMETERING DATA DATA PROCESSING	9. Cosati Codes 2202, 0906 10. Task Reference Number
11. Library distribution (Libraries of Australian Defence Group to which copies will be sent) SC SW	12. Sponsoring Agency Reference