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ROYAL AEROSPACE ESTABLISHMENT

EVALUATION OF A PROTOTYPE 6 TONE MODEM

by

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Technical Memorandum FM 28

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EVALUATION OF A PROTOTYPE 6 TONE MODEM

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SUMMARY

RAE was asked by 39 Signals Regiment (SC(V)) to evaluate a prototype 6 tone Multi-Frequency Shift Keying (MFSK) modem intended for tactical data transmissions in the High Frequency (HF) band. The main testing was to consist of extensive trials using the RAE Cobbett Hill HF Channel Simulator, but in the event also included some limited live radio trials between Bodo, Northern Norway, and RAE Cobbett Hill in Southern England.

The modem performed satisfactorily during the evaluation period and returned good availability figures, both on the simulator, and during the radio trials.

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1 INTRODUCTION

RAE was asked by 39 Signals Regiment (SC(V)) to evaluate a prototype 6 tone Multi-Frequency Shift Keying (MFSK) modem[1] intended for tactical data transmissions in the High Frequency (HF) band. This 6 tone MFSK signal format supports the ITA2 five unit start/stop code, which is sent at a rate of 75 baud using 50 millisecond elements, and is compatible with the in-service Racal LA1117 'Piccolo' modem in its single channel ITA2 mode.

The main testing was to consist of extensive trials using the RAE Cobbett Hill HF Channel Simulator[2], but during the evaluation period RAE staff had to visit Bodo to install some equipment for another purpose, and this presented an ideal opportunity to test the performance of this new modem over the demanding North Norway to Southern UK circuit.

2 SIMULATOR TESTING

Over the years RAE Cobbett Hill has developed a standard series of Channel Simulator tests, designed to investigate the performance of modems under the demanding conditions found in the real-life HF band. During these tests character error rates are measured continuously using an RAE designed error test set, consisting of a standard Trend Data Signal Analyser interfaced to an Acorn BBC Microcomputer. A special test set is required for HF radio data transmission links, because many of the commercially available test sets designed for land line circuits fail to retain character synchronisation during high error rate periods; which on HF circuits are caused by a combination of fading, multipath dispersion and interference. Realistic channel availabilities can only be determined at HF if all missed characters are counted as errors, and the fact that a test set failed to synchronise cannot then be used as an excuse for concealing poor modem performance.

A list of standard RAE simulator test parameters appears in the Appendix. These tests are largely based on the work of Ralphs[3], and some confidence may be gained from comparing measured and published results. A major problem with this type of testing is caused by the Simulator's Raleigh fading model, which demands that fading tests have to be run over very long periods to ensure enough occurrences of the worst possible conditions, in order to produce statistically reliable results. At the RAE standard fading rate of 12 fades per minute, which is used during multipath testing, each test is run for a minimum of 100000 characters at 75 baud.

During the simulator tests the modem was used exclusively in its non-diversity mode.

3 RADIO TRIALS

The proposed simulator evaluation period coincided with an RAE visit to Northern Norway for other work, and this gave an opportunity for some live radio trials over the often difficult and demanding circuit from Bodo to RAE Cobbett Hill. 39 Signals Regiment were very keen to support this trial as part of the overall modem evaluation, and loaned a complete 100 watt HF field station and error test set for use in Norway. The Norwegian authorities kindly allowed the use of a 6 to 30 MHz wideband conical monopole antenna at their Seines transmitting station. At Cobbett Hill two Racal RA1771 receivers were used together with their respective antennas consisting of a sloping vee and conical monopole, thus enabling the modem to operate with some limited degree of diversity. Any trials of this modem had to be done whilst RAE staff were engaged in other work, and hence it was only possible to run trials in one direction, *ie* transmitting from Bodo and receiving at Cobbett Hill. Character errors were monitored at Cobbett Hill using the RAE modified data test set, which was described in paragraph 2.

Frequency planning for these trials was done using a CCIR 340 computer prediction program, but because of other activities between Bodo and Cobbett Hill the choice of operational frequency was limited, and in the event turned out to be less than ideal, as can be seen from the oblique ionogram shown in Fig 5.

4 RESULTS

4.1 Simulator

Graphs showing the outcome of the simulator testing are shown in Figs 2 to 4, and are largely self explanatory. Measured performance curves for a standard 75 baud Frequency Exchange Keying (FEK) modem are shown for comparison purposes. Performance against multipath dispersion (Fig 4) appeared to be relatively poor, but the simulator multipath test is particularly severe because both fading paths have the same median level, which must increase the probability of losing discrete tones. The performance of the comparison FEK modem was better at delays of less than 5 ms because any successful FEK implementation should continue to deliver adequate performance with only one tone. However, the strength of MFSK was clearly illustrated by its improved performance at delays of greater than 5 ms.

In addition to these tests the modem's tolerance of frequency offsets and Doppler shift was investigated. The modem would produce its full specified performance with frequency offsets of up to 70 Hz, and once synchronised would remain functional if the frequency offset was changed linearly at a rate of 2 Hz/second, which is the maximum rate of change of Doppler shift available on the RAE Channel Simulator. When the operating frequency is offset the modem has to be manually synchronised to place its two synchronising tones in their appropriate filter slots, which is easily achieved using push button switches in conjunction with an LED display.

4.2 Radio trials

The aim of trials such as these is to produce an availability figure for the equipment under test, which depends on a preset error rate criterion. This section has generally used an availability criterion of 3 character errors per 1000 characters, averaged over 5 minutes, *ie* any 5 minute period with an error rate of better than 3 in 1000 is considered to be 'available', and worse than 3 in 1000 considered to be 'unavailable'. The trials of this modem consisted of 33, 5-minute periods, of which six produced more than 3 in 1000 character errors. However, if the criterion is set at 1 in 100 the modem was available for 32 of the 33, 5-minute periods.

5 CONCLUSIONS

Considering that this modem was a spare-time development using simple Digital Signal Processing (DSP) techniques, based around a relatively slow 8 bit microprocessor, the performance was found to be good, both on the air and on the simulator. Multipath performance has been discussed in paragraph 4.1, and compares with other MFSK modems in this respect (Ralphs page 100), and was found to be superior to the comparison FEK modem at the longer time delays often encountered on short, tactical, skywave circuits.

The live radio trials were essentially limited by other activities. During these short periods this modem gave good communications availability at low signal levels, but the multipath delays (Fig 5) were insufficient to explore its full performance.

Acknowledgments

RAE Farnborough would like to thank CHOD Norway, NDRE, Oslo and the Common/Seines staff whose kind co-operation, under the auspices of Anglo-Netherlands-Norwegian (ANN) Collaborative Panel 1,24, made these trials possible.

Appendix

STANDARD SIMULATOR TRIALS' PARAMETERS

(a) Signal to noise ratio

Frequency offset	0
Groundwave level	110 dB (relative level for simulator scaling)
Skywave 1 to 4	0
Signal to noise ratio	+5 dB to +16 dB normalised per Hz/bit (telegraph rate modems)

(b) Fading

Frequency offset	0
Groundwave level	0
Skywave 1	110 dB (relative level for simulator scaling)
Delay 1	0
Fade rate 1	0.0833 Hz to 10 Hz (5 to 600 fades/min)
Signal to noise ratio	40 dB normalised per Hz/bit
Skywaves 2 to 4	0

(c) Combination multipath and fading

Frequency offset	0
Groundwave level	0
Skywave 1	110 dB (relative level for simulator scaling)
Delay 1	0 to 11 mS
Fade rate 1	0.2 Hz (12 fades/min)
Skywave 2	110 dB (relative level for simulator scaling)
Delay 2	0 to 11 mS
Fade rate 2	0.2 Hz (12 fades/min)
Skywaves 3 and 5	0
Signal to noise ratio	40 dB normalised per Hz/bit

(d) Frequency tolerance and Doppler shift

Modem characteristics vary widely due to system and tone filter bandwidth differences.

As a general guide, frequency offsets up to 100 Hz, and maximum rate Doppler shift of 2 Hz/sec to an absolute offset of 35 Hz, provide realistic figures for airborne HF systems.

REFERENCES

No.	Author	Title, etc
1	R.C. Hunt	A multi-frequency shift keyed modem. Journal of the Royal Signals
2	R.C. Bagwell	Improving HF system simulation. RAE Technical Memorandum FM 5 (1988)
3	J.D. Ralphs	The principles and practice of multi-frequency telegraphy. Institution of Electrical Engineers Telecommunications Series

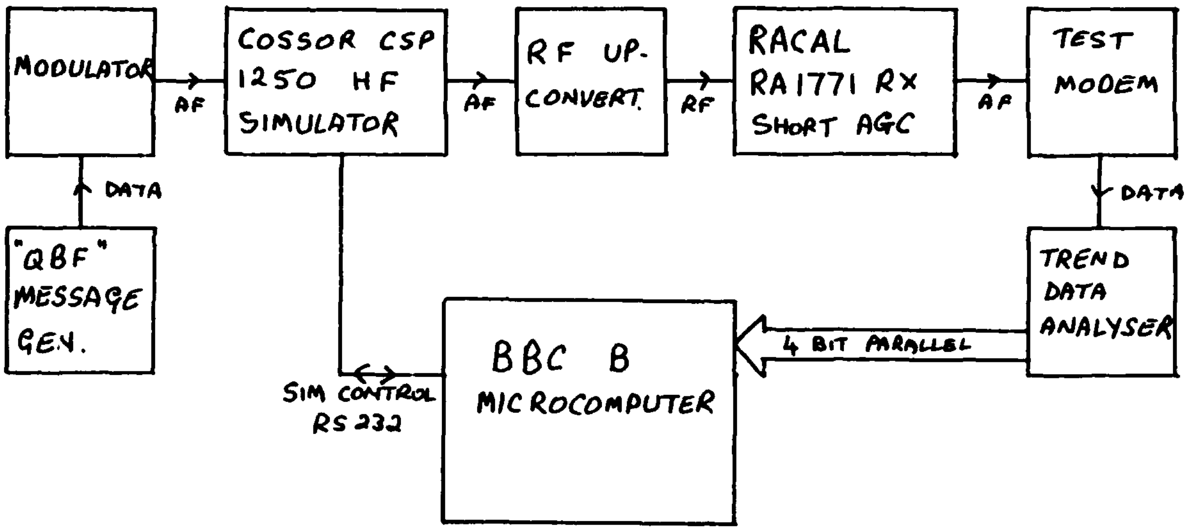


Fig 1 RAE Cobbett Hill HF Channel Simulator

Fig 2

SINGLE PATH (non-fading)

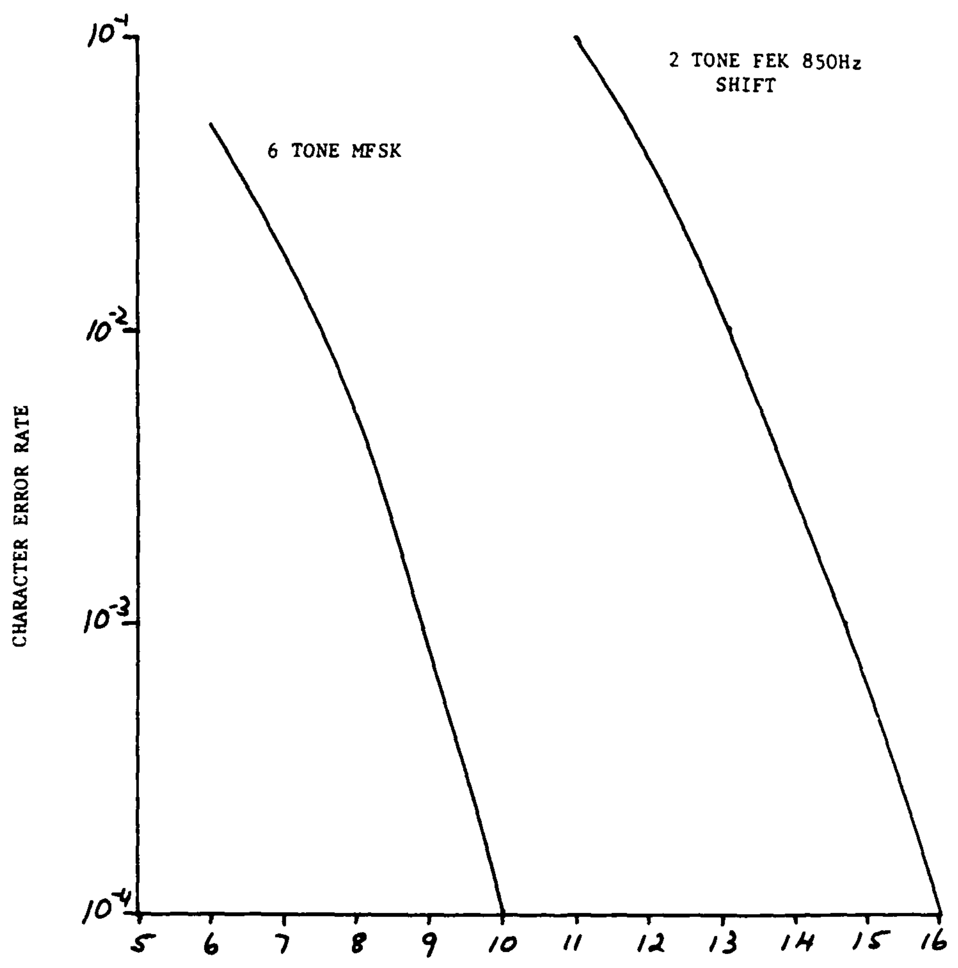


Fig 2 Normalised signal to noise ratio (dB)

SINGLE FADING PATH (non-diversity)

normalised sig to noise ratio 40 dB

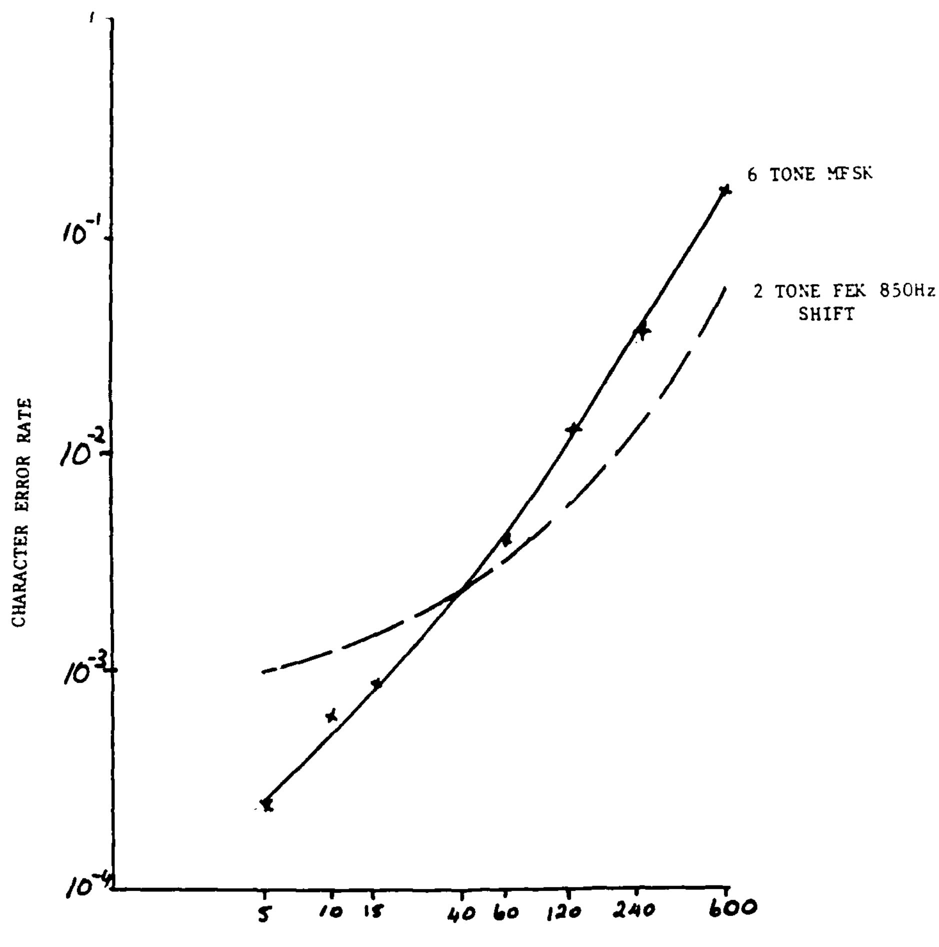


Fig 3 Fade Rate (fades per minute)

Fig 4

TWO FADING PATHS (12 fades per minute)

normalised sig to noise ratio 40 dB

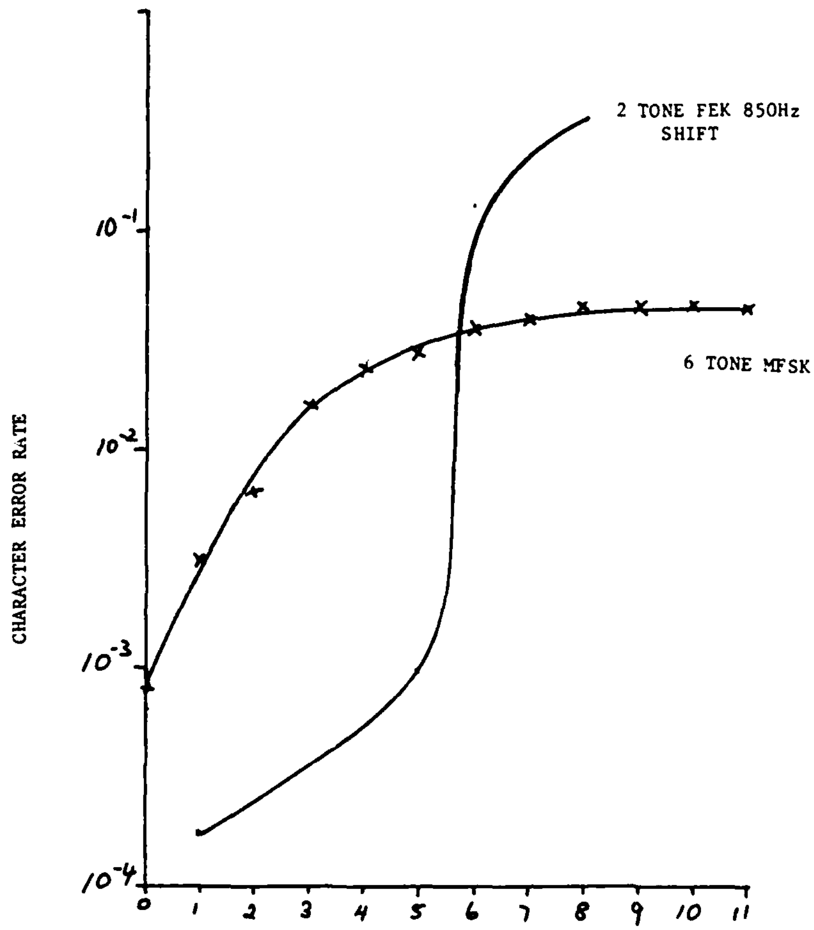
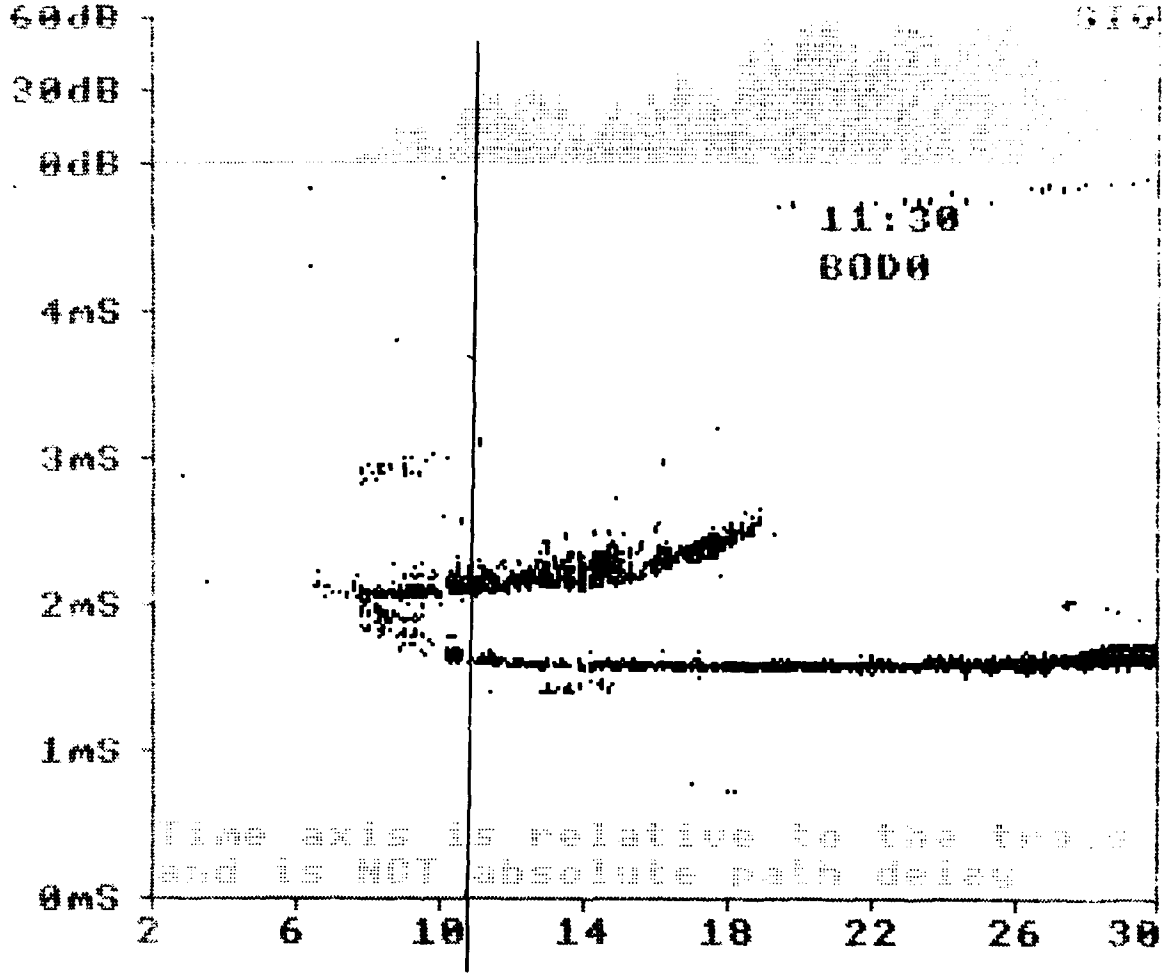


Fig 4 Differential multipath delay (mS)

Fig 5



Trials' Frequency
(11,200 kHz)

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Fig 5 Oblique ionogram Bodo to Cobbett Hill (recorded during 6 tone modem trials)

Fig 6a&b

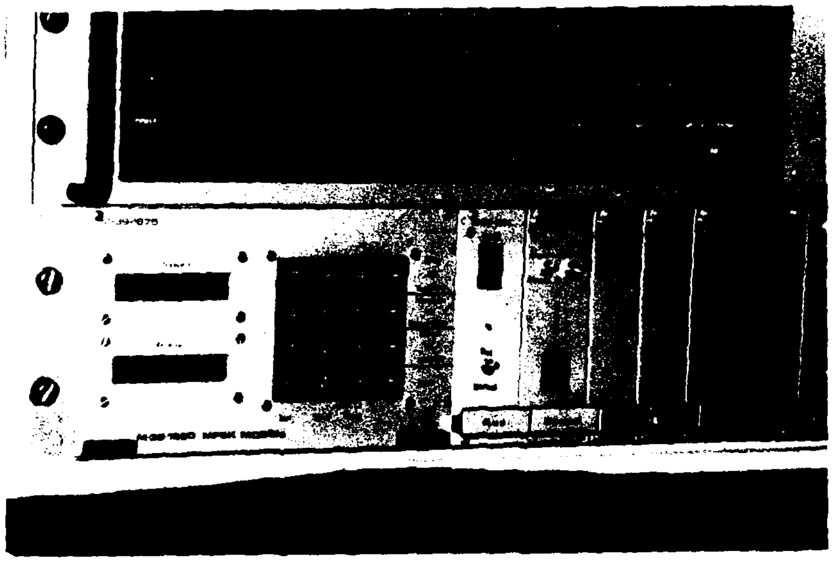

Fig 6a Base modem

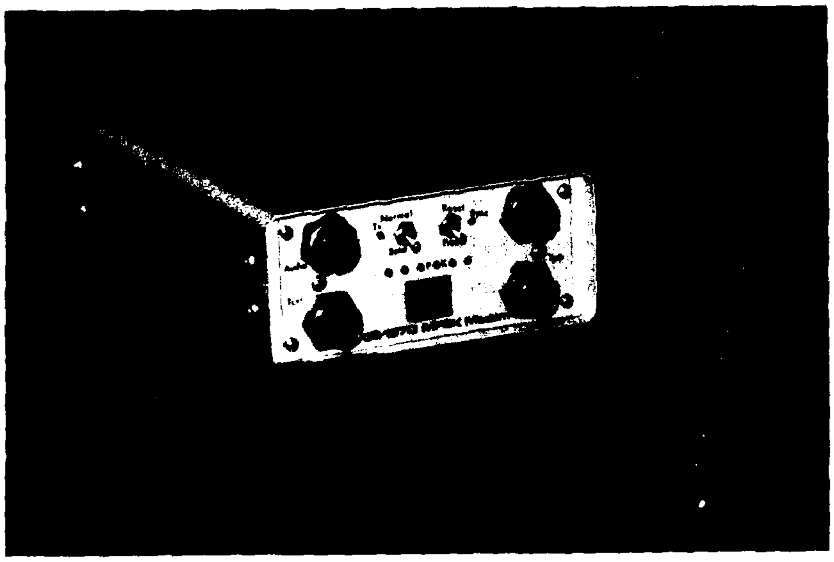

Fig 6b Field modem

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17. Abstract

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