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REPORT 7271

EVALUATION OF A CCITT
RECOMMENDATION V.36
COMPATIBLE GROUP BAND MODEM

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File: Y12/3/9

Case: 12026

RDI :

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In 1980 Telecom Australia plans to introduce a new data communications network known as a Digital Data Network (DDN). Long haul transmission between network centers will be over the existing FDM network, initially at rates of 64 kbit/s or 72 kbit/s. For long haul transmission at these speeds, data modems operating over an FDM group circuit will be used.

The Research Department of Telecom Australia has purchased three group band data modems of the same model for evaluation. This report contains results of laboratory measurements performed on those modems.

The results of the measurements show that the modems performed satisfactorily. The performance of the modem with respect to data clock jitter may require further study.

Since performing the measurements, the modems have been operating continuously in a field test for over three months without any problems.

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(Sgd.)
for Director, Research

RESEARCH LABORATORIES - REPORT 7271

EVALUATION OF A CCITT RECOMMENDATION V.36 COMPATIBLE GROUP BAND MODEM

1. INTRODUCTION

In 1980, Telecom Australia plans to introduce a new data communication network known as a Digital Data Network (DDN). The network will be initially designed to support leased line data services. Long haul data transmission between network centres will be over the existing FDM network, initially at rates of 64 kbit/s or 72 kbit/s. The 64 kbit/s data stream will be the basic building block of the DDN. For long haul transmission at 64 and 72kbit/s, data modems operating over an FDM group circuit, will be used.

The Research Department has purchased three TRT Sematrans 72KB group band modems for evualation. This report contains results of laboratory measurements performed on these modems.

2. DESCRIPTION OF MODEM TESTED

The TRT Sematrans 72KB group band modem is intended for synchronous transmission of 48, 56, 64 or 72 kbit/s binary data signals over a standard group circuit. Changeover from one bit rate to another is affected by changing a crystal and restrapping some cards. The modem uses a scrambler to avoid high amplitude spectral components on the line data signal. A line coding technique known as Class 4 Partial Response is used in the modem. The modulation technique employed in the modem results in a line data signal spectrum that is sinusoidal in amplitude, with a spectral null at 76, 72, 68 or 64 kHz for bit rates of 48, 56, 64 and 72 kbit/s respectively, and with another null at 100 kHz. The nominal level of the line data signal is - 6 dBm0, ±1 dB. The modulation technique also produces a 100 kHz carrier which is effectively added to the line data signal at a level of - 9 ±0.5 dB relative to the line data signal. The complete line signal corresponds to a single sideband signal with a carrier at 100 kHz. A group pilot can be injected externally at a frequency of 104.08 kHz.

By means of a strappable option, only available at a rate of 64 kbit/s, an extra zero at 84 kHz can be inserted in the line data signal, allowing injection of a group pilot at 84.08 or 84.14 kHz. In two of the three modems purchased, the receiver derived 100 kHz carrier phase is manually adjusted to compensate for phase deviations between the data signal and the 100 kHz carrier introduced by the transmission path. In the third modem this phase adjustment is carried out automatically.

3. APPLICABLE CCITT RECOMMENDATIONS AND INTERNATIONAL STANDARDS ORGANIZATION STANDARDS

The majority of tests covered in this report are not included in any CCITT Recommendations. However, compatibility with relevant CCITT Recommendations and ISO standards has been checked where possible.

The CCITT Recommendation applicable to modems using group band circuits for synchronous data transmission is Recommendation V.36 (Ref. 1). Although the TRT Sematrans 72KB modem does not claim to be compatible with Recommendation V.36, it has been designed to be compatible with the draft Recommendation for V.36.

Other applicable CCITT recomendations are: V.54 (Ref. 2), G.241(f), (Ref. 3), H.14B (Ref. 4), and H.52 (Ref. 5). Compatibility with Recommendation V.54 is covered in para. 4. Recommendation G.241(f) is concerned with the limits of the power spectrum emitted about the pilot frequency. Checks using a spectrum analyser show that this Recommendation is met by the modem for the case using a 104.08 kHz pilot. Recommendation H.14 lays down the characteristics of a group link for the transmission of wide spectrum signals. The number of cascaded group links that the modem should satisfactorily operate over is covered in Recommendation V.36. Recommendation H.52 is concerned with:

(i) The maximum mean power level of the transmitted group spectrum.

(ii) The limitation of the power level outside the band 60-108 kHz.

Both these conditions are met by the modem.

In accordance with Recommendation V.36, the modem uses interfaces compatible with Recommendation V.35.

The mechanical interface is in accordance with ISO standard 2593 which recommends connectors and pin numbering for use with equipment having electrical interface compatible with CCITT Recommendation V.35.

4. INBUILT TEST AND FAULT LOCATION FACILITIES

4.1 Looping facilities

The modem is provided with several self test and fault location facilities.

The looping facilities provided are loops 2 and 3 as interchange conditions affected as a consequence of the loops do not comply exactly as is defined in CCITT Recommendation V.54.

Loop 2 (far end interchange looping) can be controlled at the local modem either remotely via circuits 103 and 141, or by a front panel switch. When initiated, the local modem sends a 61.538 kHz tone to the far end modem to effect the looping. Loop 2 can also be implemented manually at the far end modem by a front panel switch.

Loop 3 (local line looping) can be controlled at the local modem either remotely via circuits 103 and 141, or by a front panel switch.

4.2 Inbuilt test generator

By means of a front panel switch the scrambler in the modem can be fed with a permanent "1" state. The local or far end modem (depending on looping conditions) should reconstitute the received data as a permanent "1" state if the modem is operating correctly, and the transmission medium is error free. If a "0" state is detected by the modem receiver this is flagged as an error via a front panel LED. By intelligent use of the looping facilities and the test generator the modem and/or transmission medium can be tested for errors.

5. GENERAL INFORMATION ON THE TESTS

All tests were conducted using an externally supplied data clock at a frequency of 64 kHz. In all cases, the tests were conducted on more than one modem to check for any differences between modems. No significant differences were detected.

After testing was completed, all the modems were reconfigured to allow operation at 72 kbit/s. One of the modems was then found to be faulty. The fault was traced to a particular card and this card was sent back to the manufacturers for repair. It should be noted that the particular fault only showed up when the modem was operating at 72 kbit/s.

6. DESCRIPTIONS AND RESULTS OF TESTS

6.1 Bit Error Rate vs Signal to Noise Ratio

Fig. 1 shows the test setup used for this test. The 12 dB amplifier is required to make up for the 6 dB loss in the adder, and the 6 dB difference between the nominal modem group band send and receive levels.

Initially, with the noise generator output level set to zero, the level of the group band signal to zero, the level of the group band signal transmitted by the modem is measured by the true RMS meter, and this value is noted. The level of noise is then increased in steps, and for each step increase the error rate as measured by the data test set is noted. For each step increase in noise, the level of the noise only is measured by the true RMS meter after operating the switch. This value is also noted.

The signal to noise ratio can then be calculated from the dB difference between the measured level of the group band signal with no noise added, and the measured level of the noise for the various error rates. A correction needs to be made to the figure as calculated above to allow for the fact that the noise bandwidth is marginally wider than that required to affect any level decision in the modem. The bandwidth of the modem receive group band filter determines the actual bandwidth of noise that will affect the modem. This filter is the dominent filter as the post demodulation filter was measured and found to have a 3 dB bandwidth of 58 kHz. The modem receive group band filter bandwidth was measured and found to be 43 kHz at the 3 dB points. The bandwidth of the group band filter used in the test setup was also measured and found to be 53 kHz. Because both the modem receive group band filter and the group band filter used in the test setup are steep sided, we can assume that the equivalent noise bandwidth is equal to the 3 dB bandwidth for these filters. Thus the correction to be made to the calculated signal to noise ratio is: 10 log (53/43) = 0.90 dB.

The results of this test are plotted in Fig. 2. A theoretical curve for the Sematrans modem is also plotted in Fig. 2. This theoretical curve is obtained from Ref. 6 after making the following three adjustments:

(i) The curve given in Ref. 6 (p 55) is for ideal binary. The signal to noise degradation of Class 4 Partial Response over ideal binary is 2.1 dB (Ref. 6 - p 91).

(ii) For optimum receiver noise performance, the Class 4 shaping should be divided equally between the transmit and receive sections of the modem. In the Sematrans modem all the shaping is done in the transmit section of the modem. This gives a reduction in signal to noise margin at the modem receiver of approximately 1 dB.

(iii) As discussed earlier, the bandwidth of noise that will affect the modem is 43 kHz. The curve given in Ref. 6 (p 55) is for the Nyquist bandwidth (32 kHz). Therefore the adjustment to be made in this case is 1.3 dB.

Thus the total adjustment to the theoretical curve that has been made is: 1 + 2.1 + 1.3 = 4.4 dB.

It should be noted that a more tightly designed modem receive group band filter would give an improvement in signal to noise ratio.

The results given in Fig. 2 show that the Sematrans modem is within 2 dB of the theoretical performance that could be expected from this type of modem.

6.2 Sensitivity to Group Band Phase Jitter

6.2.1 Sinewave Jitter: Fig 3 shows the test setup used for this test. The group band signal transmitted by the modem is modulated with a jitter free 120 kHz carrier. A phase jitter insertor, capable of inserting up to 180 degree of phase jitter, is synchronized to the 120 kHz carrier feeding the modulator. The output from the jitter insertor is used as a carrier for the demodulator, the output of which is fed to the receive section of the modem. A sinewave oscillator feeding the jitter insertor, controls the frequency and amplitude of phase jitter. The amplitude of phase jitter inserted onto the 120 kHz carrier is monitored by the oscilloscope which is triggered by the jitter free 120 kHz carrier feeding the modulator. For various sinewave oscillator frequencies, the output level of the oscillator was increased until errors were registered on the data test set. The resulting jitter amplitude as monitored by the oscilloscope was then noted. The results obtained in this test are plotted in Fig. 4.

Results obtained in this test give a measure of the cutoff frequency of the phase locked loop (PLL) used in the modem receiver to recover the 100 kHz carrier. The carrier PLL cutoff frequency is normally designed to allow for factors such as noise, presence of 50 and 100 Hz carrier components, and ability to track any expected phase hits. As such, it is considered that in the case of the Sematrans modem the carrier PLL cutoff frequency is adequate.

The results also give an indication of the modem's ability to tolerate any carrier phase error. Within the flat portion of the curve, the modem can tolerate up to approximately 25 degree peak to peak carrier phase error. From information derived from Ref. 7 the theoretical maximum peak to peak carrier phase error that a three level Class 4 Partial Response type modem can tolerate before the receive eye pattern is completely closed is 42 degrees.

Under normal operating conditions the modem receiver eye pattern was closed approximately 25%. Taking into consideration this factor plus any other imperfections in the modem, it is considered that the modem performed satisfactorily in this test.

6.2.2 Step Change: The test setup used for this test is similar to that shown in Fig. 3. In this case the carrier for the demodulator is fed from the same 120 kHz carrier that supplies the modulator. A phase shifter is inserted in series with the carrier to the demodulator. The phase shifter can be set up to give a relative phase difference, in five degree increments, between the modulator and demodulator carriers. The phase difference thus set up can then be manually switched in or out producing a step phase change at group band level.

The phase difference was increased in five degree steps, and for each step the phase difference was switched in and out a number of times. The amount of phase difference required to occasionally cause errors on the data test set when the phase difference was switched in and out, was taken to be the maximum group band level step change in phase that the modem could tolerate.

The results of this test show that for a positive step change in phase difference, a shift of 20 degrees would occassionally cause errors. For a negative step change in phase difference, a shift of 15 degrees would occassionally cause errors.

Note that the results of this test are relatively inaccurate in that the phase steps can only be changed in five degree increments.

To compare the results obtained in this test with some theoretical values reference is made to Ref. 7. These show that for a peak carrier phase error of 21 degrees in a three level Class 4 Partial Response type modem, the received eye pattern will be completely closed. Taking into account the test setup and modem imperfections as discussed in para. 6.2.1, the results obtained show that modem performed satisfactorily in this test.

6.3 Minimum Break Required at Group Band Level to Cause Data Errors

For this test an analogue switch together with a 6 dB amplifier were placed in series between the modem group band transmit and receive points. A data test set was used to monitor the data passing through the modem. A pulse generator with variable pulse width was used to control the length of the break via the analogue switch. The break length was increased until the first occurrence of errors was noted on the data test set.

The results show that a break of approximately 7 µs (about one half a bit period) was sufficient to just cause data errors.

For comparison to some theoretical figures, reference is made to calculations quoted in Ref. 8. These show that for a three level Class 4 Partial Response type modem, a minimum break of 0.92 bit period (14.3 µs) will close the modem receive eye pattern.

Considering the test setup and modem imperfections as discussed in para. 6.2.1, and an additional factor of the analogue switch not producing a "clean" break, the results obtained in this test are considered to be satisfactory.

6.4 Limits of Input Level Variation

6.4.1 Slow Change: For this test an attenuator and an 18 dB amplifier were placed in series between the modem group band transmit and receive points. A data test set monitored the data passing through the modem. The attenuator was manually varied so that the level into the modem receiver varied above and below the nominal receiver input level, to the limits that caused data errors.

The results of the test show that the modem could tolerate a receive level variation of + 12 dB, and - 7. 5 dB about the nominal receive input level. Under normal operating conditions the slow changes in input level variation are smaller than ±6 dB. The modem should therefore operate correctly within the expected input level variations.

6.4.2 Step Change: For this test a similar test setup as described in para. 6.4.1 was used except that the attenuator was replaced with an analogue switch. The analogue switch could select either of two paths for the group band signal. One path (A) contained an attenuator that was set up to give the nominal group band level into the modem. The other path (B) contained an attenuator that could be preselected to give an overall increase or decrease in group band signal level into the modem receiver. A pulse generator was used to control the analogue switch for selection of paths A or B. For various settings of the attenuator in path B the pulse generator switched between paths A and B. The attenuator in path B was varied so that the level into the modem receiver varied above and below the nominal receive input level, to the limits that caused data errors.

The results of this test show that for a step in input level into the modem of up to - 4 dB, no data errors were produced. For a step change of - 6 dB an average of 12 data errors were produced. For a step change of up to + 6 dB in input level, no data errors were produced.

Under normal operating conditions the step change in input level would not be greater than ±6 dB. As the modem produced only a small number of errors for a step change in input level of - 6 dB, and no errors for a step change of up to + 6 dB, the results obtained in this test are considered to be satisfactory.

6.5 Automatic Gain Control Response Time

Whilst performing the measurements as described in para. 6.4.2 the response time of the automatic gain control (AGC) in the modem receiver was monitored. This was achieved by viewing the output signal from the AGC amplifier on an oscilloscope. The oscilloscope was triggered by the pulse generator. The time taken for the signal out of the AGC amplifier to return to its nominal output level after each step change was measured.

Results of this test show that for a step change in input level of up to ± 6 dB the response time of the AGC amplifier was less than 10 ms.

6.6 Maximum Tolerable Group Band Frequency Error

A similar test setup as shown in Fig. 3 was used for this test. The carrier for the demodulator was fed from an independent oscillator. The frequency of the oscillator was varied above and below 120 kHz to the limits that caused data errors.

The results obtained in this test show that the modem can tolerate a maximum group band frequency error of up to + 1.7 kHz and - 2.2 kHz.

CCITT Recommendation H.14B (Ref. 4) specifies that the maximum frequency error over a group link shall not exceed 5 Hz. The modem will therefore operate satisfactorily over group links which conform to CCITT Recommendation H.14B with regards to maximum frequency error.

6.7 Sensitivity to Transmit Data Clock Phase Jitter

Fig. 5 shows the test setup used for this test. The 64 kHz clock feeding the data test set and modem is supplied via a jitter insertor, capable of inserting up to 90% peak to peak jitter. A sinewave oscillator feeding the jitter insertor controls the frequency and amplitude of phase jitter. The amplitude of jitter inserted onto the 64 kHz clock is monitored by the oscilloscope. Because the data test set generates data from the 64 kHz clock, the data will have the same amplitude and frequency of phase jitter as the 64 kHz clock. Thus any data errors will not be due to incorrect clocking in of data in the modem transmitter. For various sinewave oscillator frequencies, the output level of the oscillator was increased until errors were registered on the data test set. For each frequency the peak to peak jitter amplitude required to cause data errors was noted.

Results obtained in this test are plotted in Fig. 6. It can be seen that there are particular jitter frequencies where the modem cannot track a high level of data clock jitter. The particular points of interest are at about 8 Hz, and the sharp nulls occurring at higher jitter frequencies. This effect is due to the method employed in the modem receiver to recover the receive data clock. The demodulated data signal after filtering and full wave rectification is used to synchronize a divider. The divider supplies the recovered clock from a signal at 100 times the bit rate. Although the mechanism that causes the modem to mistrack for particular data clock jitter freqencies is not clear, it appears that there may be a beating effect between the data clock jitter frequency and the signal supplying the divider.

The significance of this effect is unknown at this stage, but should be kept in mind for future reference.

7. CONCLUSIONS

The results of measurements on a type of group band data modem have been recorded in this report. Since performing the measurements, the modems have been operating continuously in service for over three months without any problems.

A fault was detected in one modem when the modem was reconfigured to allow operation at 72 kbit/s. The faulty card was returned to the manufacturers for repair, and at the time of writing this report the card had not been returned.

The modem's inability to track some particular data clock jitter frequencies may require further study.

Overall the modem performed satisfactorily and can be classed as acceptable.

ACKNOWLEDGEMENT

The author wishes to thank Dr. B. Smith for his valuable assistance in the measurement program and preparing this report.

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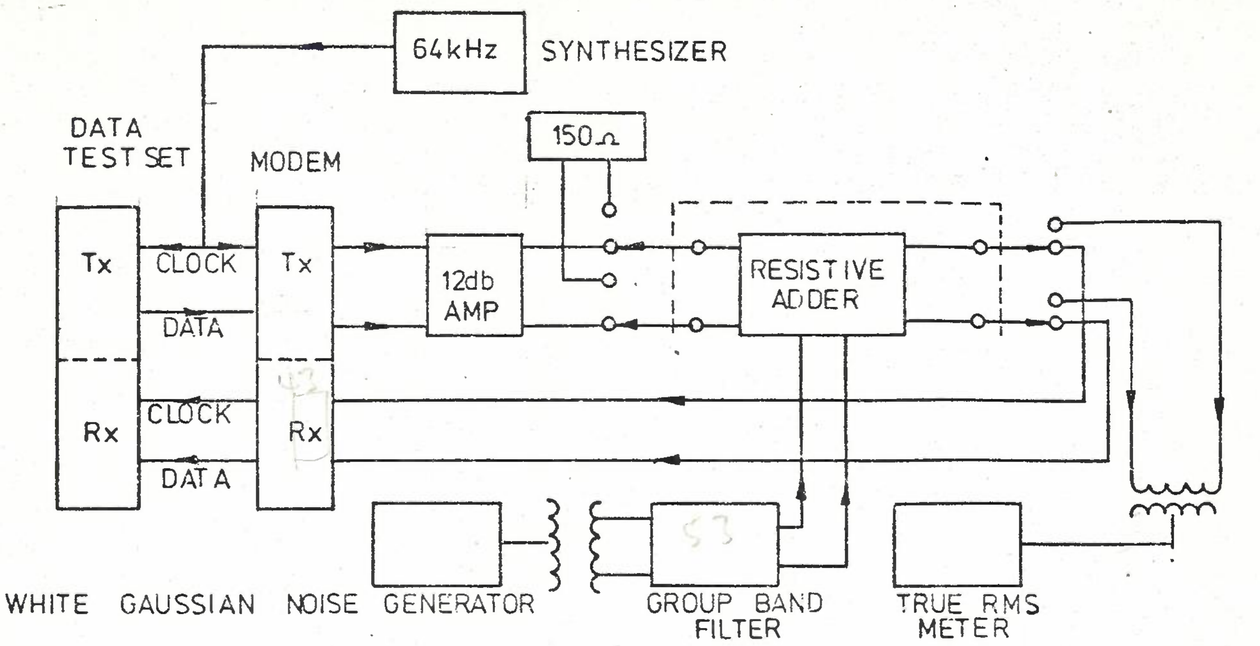

FIG.1 TEST SETUP FOR MEASUREMENT OF BIT ERROR RATE VS SIGNAL TO NOISE RATIO

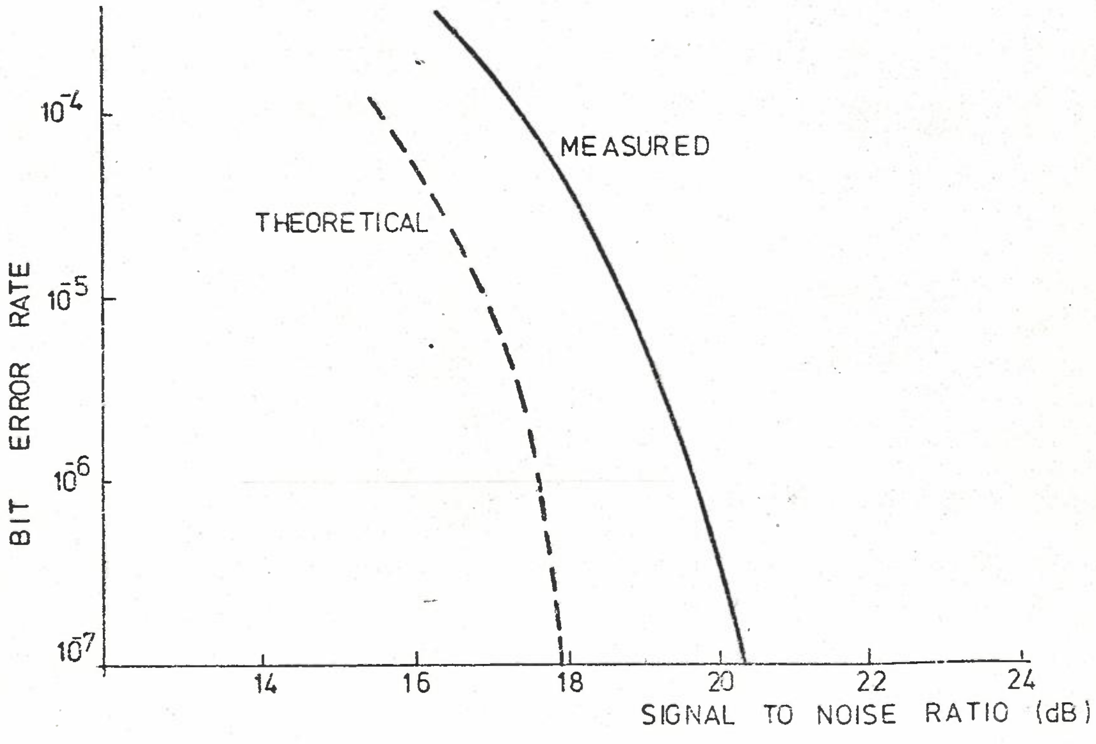

FIG.2 MODEM PERFORMANCE AT 64 kbit/s UNDER ADDITIVE WHITE GAUSSIAN NOISE CONDITIONS WITH A NOISE BANDWIDTH OF 43kHz

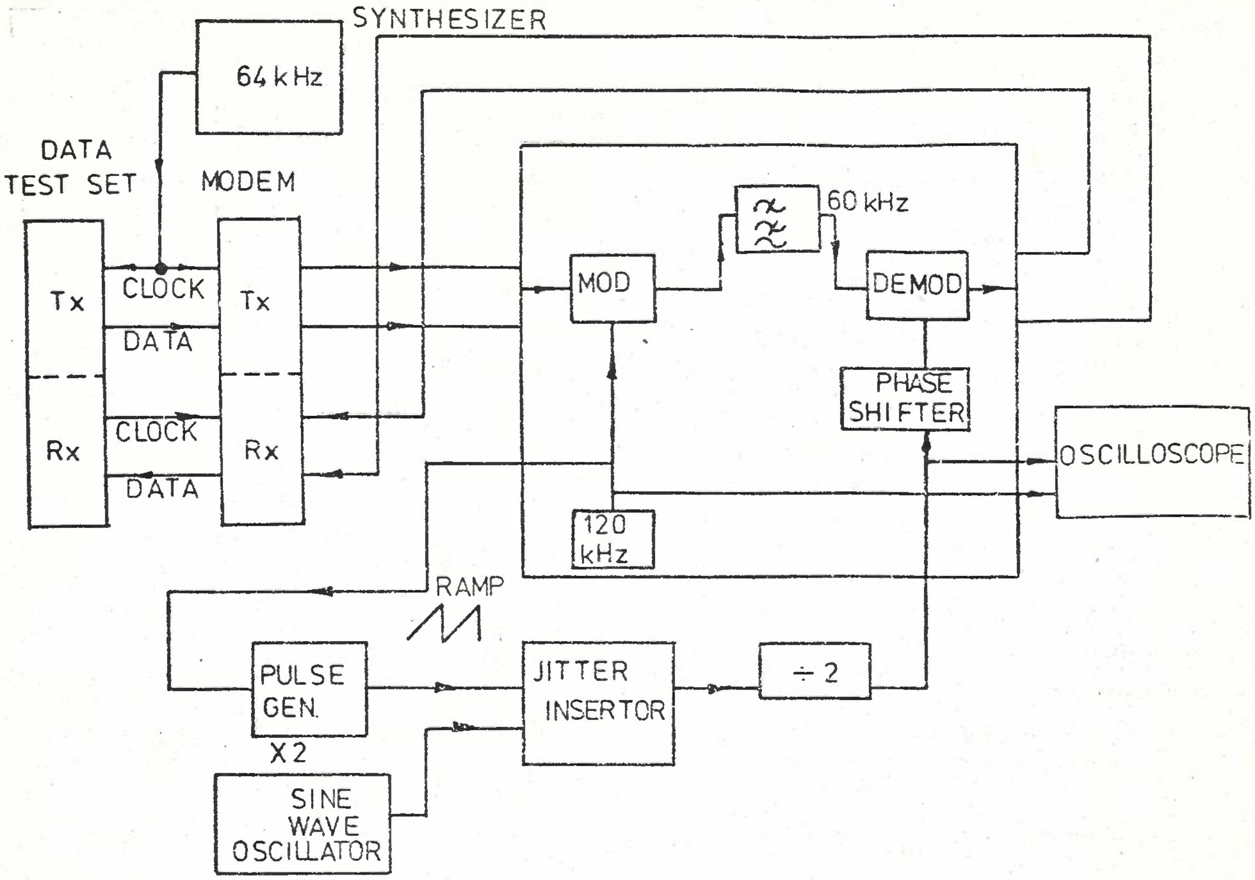

FIG. 3 TEST SETUP FOR MEASUREMENT OF SENSITIVITY TO GROUP BAND PHASE JITTER

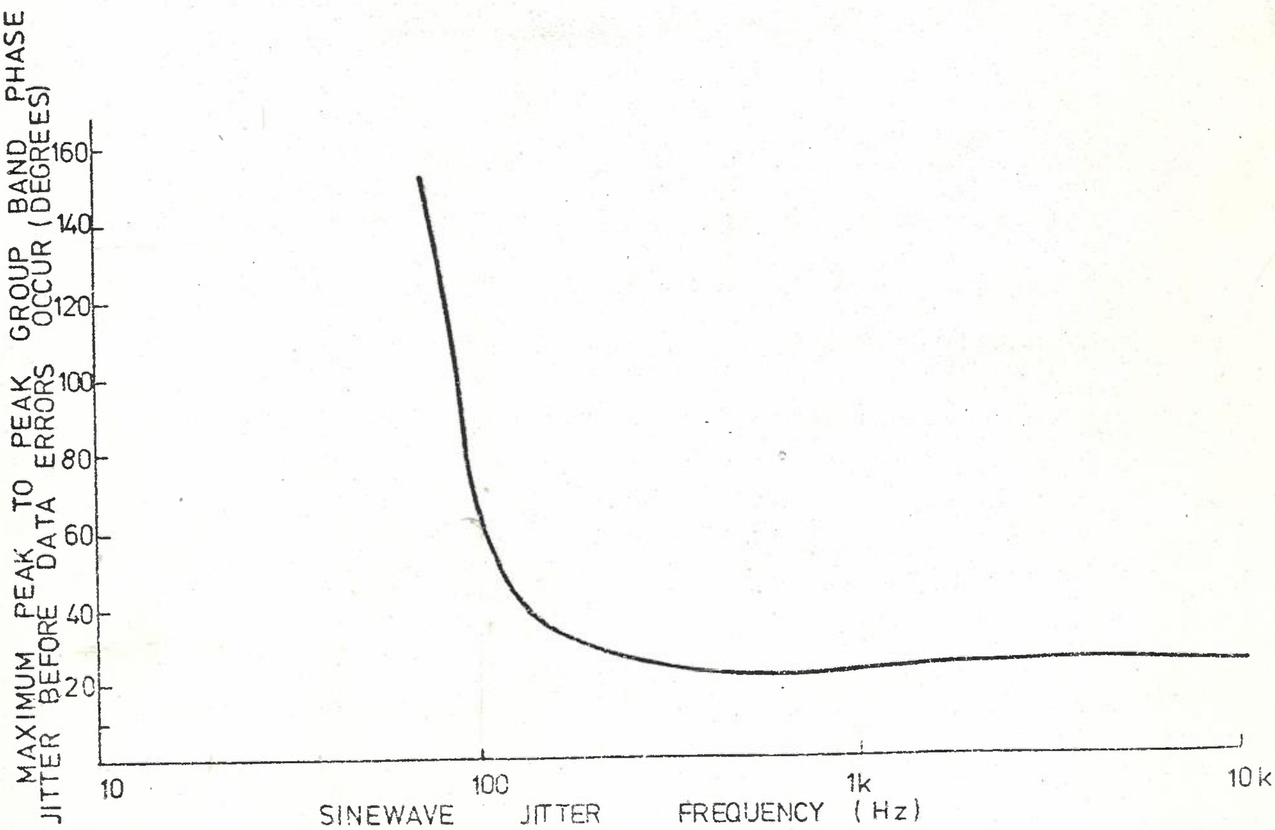

FIG.4 MODEM PERFORMANCE UNDER GROUP BAND PHASE JITTER CONDITIONS

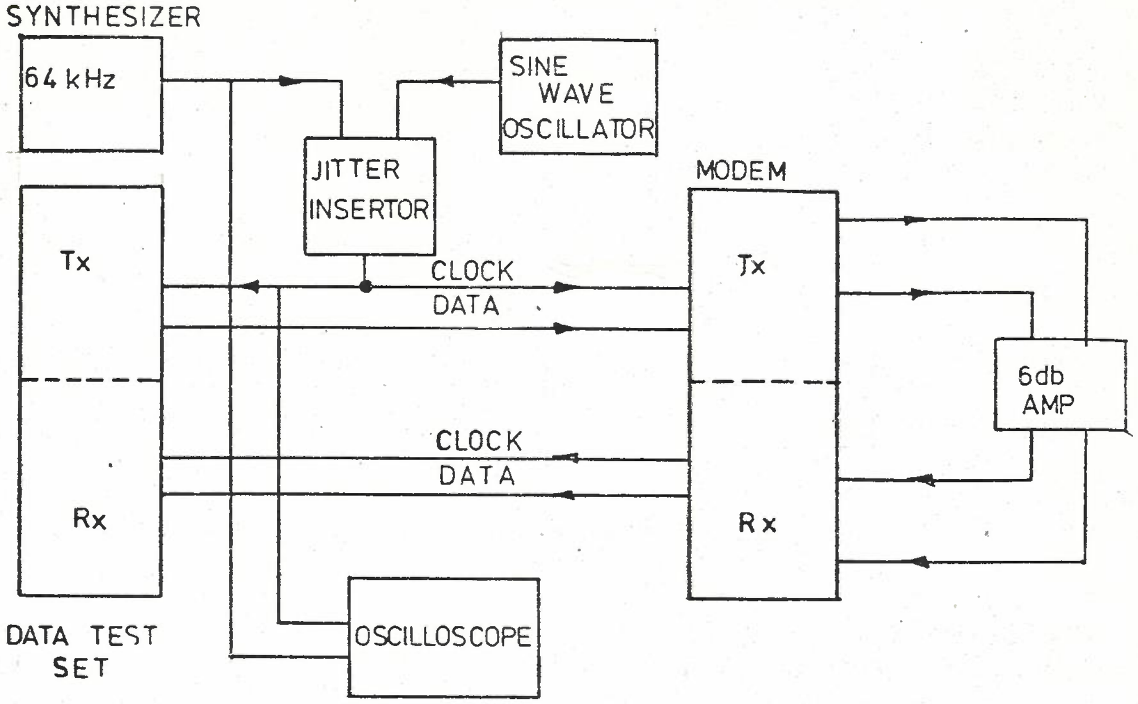

FIG.5. TEST SETUP FOR MEASUREMENT OF SENSITIVITY DATA CLOCK PHASE JITTER

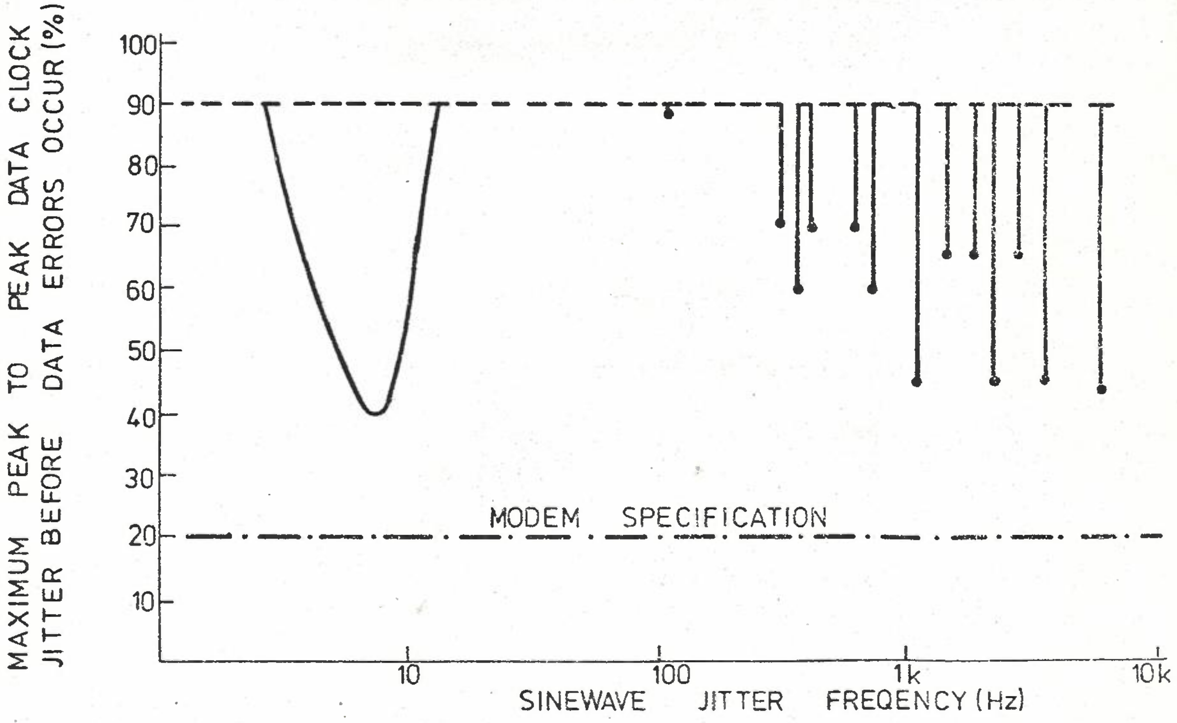

FIG.6. MODEM PERFORMANCE UNDER DATA CLOCK PHASE JITTER CONDITIONS