Understanding 300 Baud Modem Specifications

National Semiconductor
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Understanding the specifications commonly used for 300 Baud modems presents a major hurdle for first time modem buyers. Not only are some specifications subtle, but few standards exist, so apparently similar specifications may reflect vastly different performance. Understanding the conditions under which a modem is actually tested, and how those conditions will affect performance, will allow these specifications to provide useful insight into modem performance.

A MODEM EVALUATION SYSTEM

A typical modem test system is illustrated in *Figure 1*. The setup consists of two modems, the "standard" modem which is mainly used to transmit data, and the Modem Under Test (MUT) which demodulates this data. The data pattern for this transfer is generated by data pattern generator #1, and the transmitted and received data may be compared in the data analyzer. The storage oscilloscope may be used to compare transmitted and received data for distortion which is too small to cause errors detectable by the data analyzer.

A phone line simulator and noise generator may be inserted into the signal path to simulate a noisy phone line, so the MUT may be analyzed under operating conditions closely resembling actual conditions.

The data pattern generator #2 is used to exercise the MUT so it is operating under full duplex conditions. As the MUT's modulator and demodulator may interact, it is necessary that the MUT's modulator be fully exercised during modem evaluation.

It is possible to buy equipment which is capable of performing all the functions of data generation, data comparison and data quality analysis (the task of the storage oscilloscope) in one unit. Such equipment is made by several major manufacturers and greatly simplifies modem evaluation. This discussion will not combine these tasks into one unit as this allows greater insight into the parameters being measured and their relevance to the overall system.

It is common to use a modem which is identical to the MUT as the "standard" modem. This allows the total distortion, in both the modulator and demodulator to be evaluated in one measurement. As there is no accepted industry standard "ideal" modem, it is difficult to find a better alternative for the "standard" modem.

TELEPHONE LINE SIMULATORS

Modem performance will vary depending on the phone line through which it transmits. An "ideal phone line" consisting of a resistive "T" network will give generally better performance than a typical phone line, or a very bad phone line, due to the amplitude, phase, harmonic and echo distortion produced by phone lines. Telephone line simulators allow reasonable representation of actual conditions and are controllable in an engineering environment.

There are two types of phone line simulators commonly available. One class of phone line simulators only simulate the amplitude and phase characteristics of a phone line. Although these simulators are designed to operate in a 600Ω system, their input impedance is not representative of a typical phone line. (See paper by Gresh (7) in reading list at end of this article). Some modems have a dynamic range which is sensitive to the impedance "seen" looking into the phone line. (This occurs because a mismatch between the modem and the phone line causes modulation sidebands of the modulator to be reflected back into the demodulator and thus degrade the received signal to noise ratio). Thus these simulators are not particularly suitable for modeling the modem to phone line interface. This type of simulator is available as a sealed unit with input and output terminals. They are available with "typical", "worst case" and other characteristics. An advantage of this type of simulator is that they are simple to use and specify. Some normalized frequency response plots of these simulators are shown in *Figure 2*.

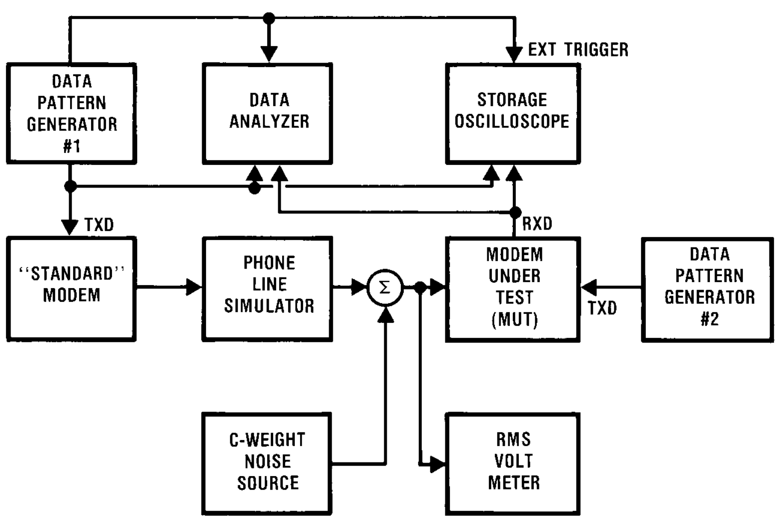

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FIGURE 1. Modem Evaluation Block Diagram

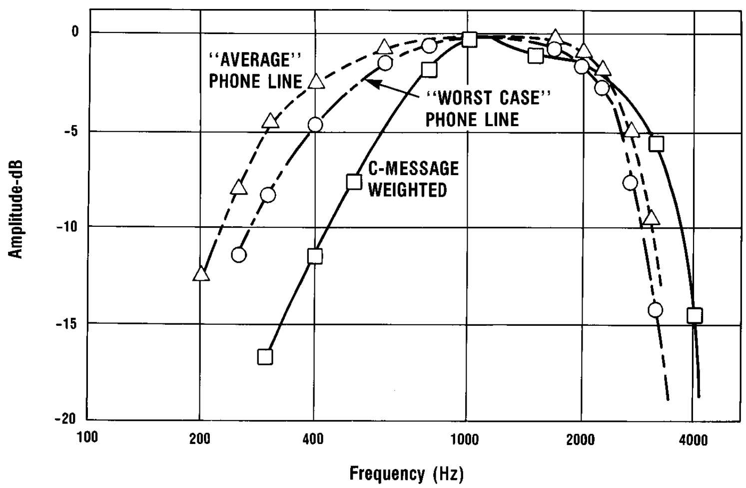

FIGURE 2. Response of Noise Weighting Filter and Phone Lines

A second class of simulators is capable of simulating a wide range of phone lines. These simulate amplitude, phase and input impedance characteristics. They consist of many units each representing a section of phone line wire. These can be interconnected at will to simulate a wide variety of phone line lengths, gauges, and configurations, including tapped and loaded lines. Although this type of simulator is flexible, no modem testing standards exist describing how it should be connected for writing specifications.

Neither of these simulators allow much flexibility in controlling attenuation through the line, or for adding noise to the line. Thus the final line simulator used will generally consist of a commercially available unit with some added hardware to allow controlled noise mixing and signal attenuation.

THE NOISE GENERATOR

The noise generator is used to simulate noise on the phone line which might adversely affect modem performance. Noise generators must be accurately specified before their effect on a given circuit can be evaluated meaningfully.

The spectral properties of noise have considerable influence on its effect on modem performance. Only noise with frequency components close to the tones used by modems will interfere with their operation. Noise with spectral components far from the modem tones will contribute to the noise power in the system and will thus affect a noise measurement, but it will not affect modem performance. It is thus necessary to use noise with well defined frequency characteristics in order to achieve a meaningful noise measurement.

A common choice of noise bandwidth is called "C-Message Weighted". The C-Weighted frequency response is shown in *Figure 2*. This response was chosen to allow comparison of noise power in relation to its effect on the perceived noise of a phone line, i.e., it is a combination of the effect of a telephone earpiece and the human ear. It is thus not entirely appropriate to modem characterization. A disadvantage of the C-Weighted response is the complexity of the filter required to generate it. In spite of these disadvantages the C-Weighted response has become almost the de facto standard of modem testing.

It is important that the noise mixer be on the MUT side of the phone line simulator. If this is not done the phone line simulator will modify the bandwidth of the noise reaching the MUT. The main effect of this is to reduce the amplitude of the noise at the skirts of the C-Weight bandwidth. This causes the noise to be concentrated around the received signal tones, and thus causes an apparent degradation of performance. This performance degradation is often erroneously attributed to the gain and phase distortion produced by the phone line simulator. This is discussed further in the discussion of bit error rate testing later in this article.

THE E.I.A. RS-334-A SPECIFICATION

The RS-334-A specification "Signal Quality at Interface Between Data Terminal Equipment and Synchronous Data Circuit-Terminating Equipment for Serial Data Transmission" published by the Electronic Industries Association (E.I.A.) gives valuable information on the measurement and specification of data distortion.

Unfortunately, many manufacturers do not specify their modems in a manner consistent with E.I.A. RS-334-A. This document discusses "isochronous distortion" of data, which is a measure of the total distortion of a serial data pattern.

Many modem manufacturers, however, prefer to discuss the data distortion in terms of "bias" and "jitter", which are more intuitive terms than isochronous distortion. Isochronous distortion can be found by summing the effects of bias distortion and jitter, so it is possible to calculate RS-334-A compatible specifications from this data.

E.I.A. make a very important point regarding all bias, jitter and bit error rate measurements and specifications:

"The result of the measurement should be completed by an indication of the period, usually limited, of the observation. For a prolonged modulation (or restitution) it will be appropriate to consider the probability that an assigned value of the degree of distortion will be exceeded."

This is a consequence of measurements made in the presence of random signals, and is typical of most modem parameters. Modems are designed to operate in conditions which are better described by probabilities (e.g. the probability that the input impedance of a phone line will fall inside certain limits, or that the signal to noise ratio at the modem will have a certain value). Thus it is important when writing modem specifications to carefully describe, and be able to interpret, test conditions.

ISOCHRONOUS DISTORTION

Isochronous distortion can be measured with the configuration of *Figure 1*. A long pseudo-random data string is transmitted by the "Standard" modem and demodulated by the MUT. This test is usually performed with no noise added to the system. As time progresses a pattern will develop on the storage oscilloscope. This buildup is demonstrated in *Figure 3* which shows the pattern at four successive time instants. As the scope was triggered by the data clock, the time T_i represents a range of times it took the data edges to propagate through the system. This is a distortion of the data edges as it represents a time in which the modem output is indeterminate, and carries no information. During the remaining time of the bit cells, however, the modem output is fixed at a mark or a space, and thus carries information.

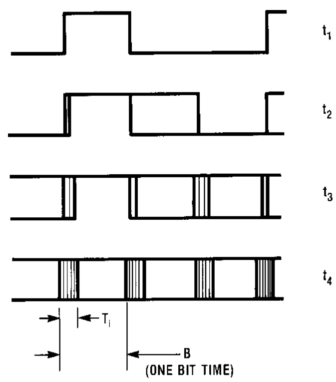

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FIGURE 3. Isochronous Distortion Pattern Buildup

From this pattern the isochronous distortion is defined to be

$$D = \frac{T_i}{B} \times 100\%$$

where B is the bit time, and T_i is the total spread of data transitions.

BIT BIAS

"Bit bias" refers to the propensity of a modem demodulator to favor a mark or a space. It is most commonly measured using the setup of *Figure 1* with an alternate (1010...) pattern from the data pattern generator #1. Note that an alternate pattern is equivalent to a 50% duty cycle square wave at half the baud rate.

After this pattern is sent for some period, a pattern as shown in *Figure 4* will build up. The rising and falling edges of the pattern do not occur at the same time relative to the data clock (the oscilloscope trigger input) and so a range of edges at the data transition are recorded. If the modem produces bias distortion the average position of the transitions will differ from the edge of the bit cell. This bias will cause the modem to show an average duty cycle at the demodulator output which differs from 50%.

From this pattern, bias as a percentage may be defined. A definition consistent with RS-334-A would be

$$\text{Bias} = \left| \frac{T_b}{B} \right| \times 100\ (\%).$$

This may be manipulated into an equivalent definition:

$$\text{Bias} = |\text{Average Duty Cycle} - 50| \times 2.0\ (\%)$$

Some modem manufacturers have used the alternate definition

$$\text{Bias} = \left| \frac{T_b}{2 \times B} \right| \times 100\ (\%).$$

There does not appear to be any apparent reason for the variation of specifications used. One possible justification for dividing by two bit times is that the distortion T_b of *Figure 4* could be considered as distortion to both the mark and the following space. Thus the distortion should be divided between the two data bits. When reviewing modem specifications it is important to know which bias definition is being used.

The 74VHC942 and 74VHC943 300 baud modems use the second definition so as to be consistent with other manufacturers of modem components. **(The 74VHC942/943 devices are direct pin, function, and spec replacements for the MM74HC942/943 devices.)**

Bit bias is amplitude dependant for some modem designs. This makes it difficult to decide under what conditions bias should be specified. *Figures 5* and *6* show the bias for the 74VHC942, the 74VHC943 and another modem plotted against signal strength. Note that for the other modem the bias is signal strength dependant, whereas for the 74VHC942 and 74VHC943 it is not. This demonstrates the necessity for specifying the conditions under which bias is measured, and the extent to which it is design dependent.

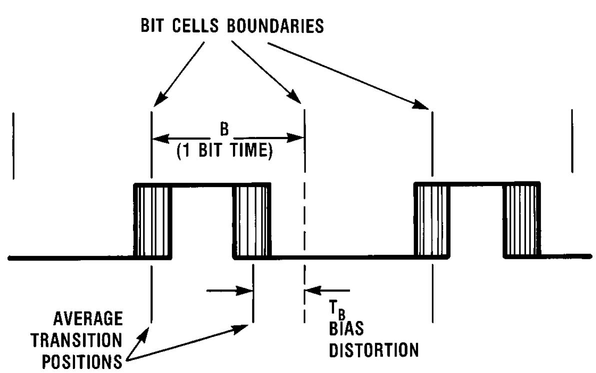

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FIGURE 4. Modem Output Pattern for Bias Measurement

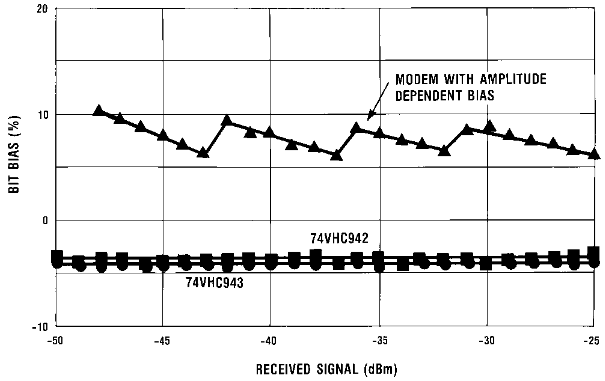

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FIGURE 5. Bit Bias vs Received Signal (Originate Mode)

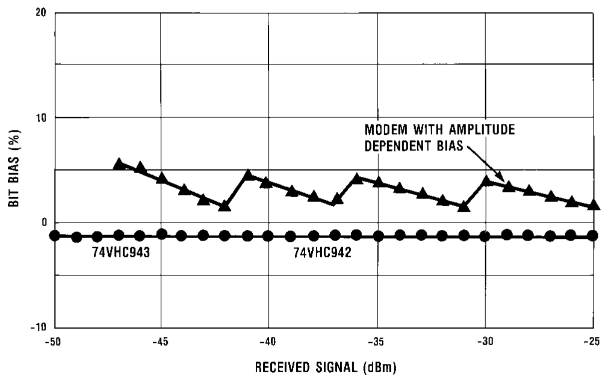

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FIGURE 6. Bit Bias vs Received Signal (Answer Mode)

BIT JITTER

Bit Jitter refers to variation of propagation delay through the data path. The term "jitter" comes from apparent movement of the data edges observed on an oscilloscope. *Figure 7* shows the pattern which will build up on the storage oscilloscope of *Figure 1* if an alternate pattern is being generated by data generator #1. The rising and falling edges of the pattern do not occur at the same time relative to the data clock, producing the variation T_j of these edges. This variation is bit jitter.

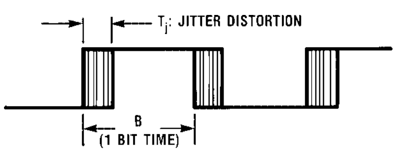

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FIGURE 7. Modem Output Pattern Showing Jitter

There are several distinct mechanisms contributing to bit jitter;

1) Intermodulation between data and carrier. 300 baud modems are asynchronous. This means the data can change at any time during a carrier cycle. The ability of a demodulator to detect this data change can vary depending on the time of the data change relative to the carrier. Thus the demodulator response varies, and jitter is produced.

2) Noise. This may come from internal circuitry, or from the phone line. When jitter is evaluated it is usually done with external noise sources squelched, so the modem, rather than the test circuit, may be evaluated.

3) Time quantization (this refers to the finite switching speed of sampled data systems). As the data is not sychronized to the modem clock, the modem may not recognize a data change for an entire clock cycle. This will cause a variation of response.

4) Data history. This contributes jitter because most demodulator circuits have memory. This is demonstrated by the circuit of *Figure 8* whose response to various input signals is shown in *Figure 9*. In Case A the data input consists of one mark. The RC network does not have time to reach equilibrium. In Case B however, the input consists of a sequence of marks followed by a space. In this case the RC network has equilibrated at the mark state. Thus the time it takes the falling edge to propagate is different in the two cases.

In summarizing these causes of jitter they may be divided into two groups.

A) Random Jitter. This comes from causes 1–3. It is purely random and cannot be influenced by the test pattern.

B) Inter Bit Distortion. This is jitter caused by data history and can be measured using the patterns of *Figure 9* which represent extremes of data history.

As these forms of distortion are very similar in their final results. They can only be distinguished using long data patterns and statistical analysis. Note that, referring to *Figure 7*, the jitter depicted is random jitter only since the data pattern is a square wave.

Discriminating between these different jitter mechanisms is valuable to a modem designer but not to a user. However, it is important that the user be aware that a jitter specification may be measured with an alternate pattern, and thus may only reflect random jitter.

Expressing bit jitter as a percentage suffers from alternate definitions as does bit bias. An RS-334-A consistent definition would be:

$$\text{Jitter} = \left|\frac{T_j}{B}\right| \times 100\%$$

but many manufacturers use the definition:

$$\text{Jitter} = \left|\frac{T_j}{2 \times B}\right| \times 100\%.$$

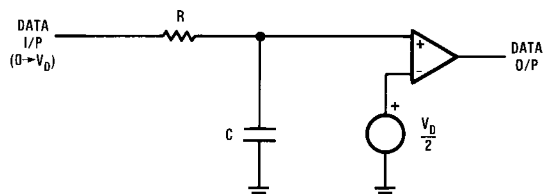

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FIGURE 8. Circuit for Inter-Bit Distortion Demonstration

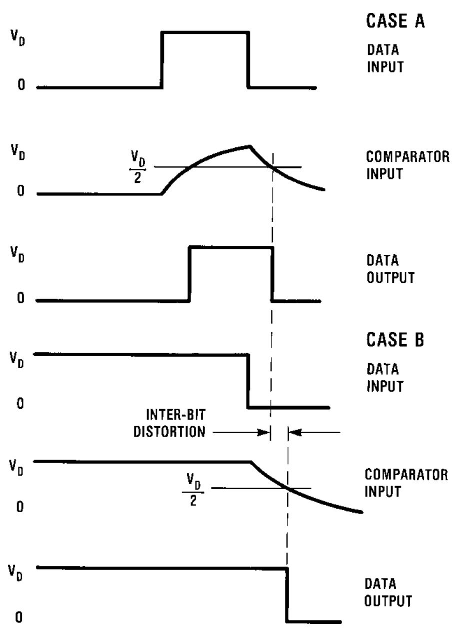

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FIGURE 9. Waveforms for Inter-Bit Distortion

Again, the reasons for the differences are not clear but could follow similar lines to those for bias.

For this reason jitter may be specified with less ambiguity by specifying the peak to peak jitter in micro-seconds. Alternately, if jitter is to be expressed as a percentage, the definition should be provided.

Bit jitter, like bit bias, is phone line dependent. For single chip modems it is often measured with an ideal (resistive) phone line as this can be easily performed on currently available integrated circuit test equipment. This will generally give "best case" results.

Some measurements of bit jitter are illustrated in *Figures 10* and *11*. Note the mode and signal strength dependence of the measurements. This data was taken on the 74VHC942 and 74VHC943 monolithic 300 Baud modems using an ideal (resistive) phone line and in full duplex mode, transmitting at −12 dBm.

ISOCHRONOUS DISTORTION, BIAS AND JITTER

For the modem user, isochronous distortion is probably the most meaningful specification of data distortion. However, some modem manufacturers only provide information on bias and jitter. Thus a conversion from these terms to isochronous distortion would be useful.

Isochronous distortion, being a measure of total distortion, is approximately the sum of bias, random jitter and inter-bit distortion. Before these numbers can be added, it must be assured they have been measured and defined in the manner consistent with specification RS-334-A.

BIAS, JITTER AND UART PERFORMANCE

Data distortion is only important insofar as it affects the interface between a modem and the computers which are communicating through it. Generally a computer interfaces to a modem through a UART (Universal Asynchronous Receiver Transmitter). This UART takes byte wide data from the computer and serializes them so they are suitable for transmitting through the modem. The UART at the receiving modem takes this serial data and converts it back into parallel form. Referring to *Figure 1,* UART operation is performed internally by the data generator and analyzer.

Before the effect of data distortion on a UART can be estimated the technique by which a UART performs serial to parallel data conversion must be understood. This is illustrated in *Figures 12* and *13*.

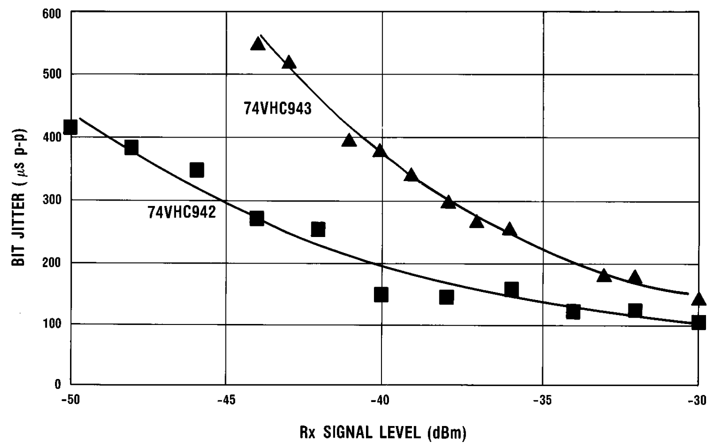

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FIGURE 10. Jitter vs RX Signal (Originate Mode)

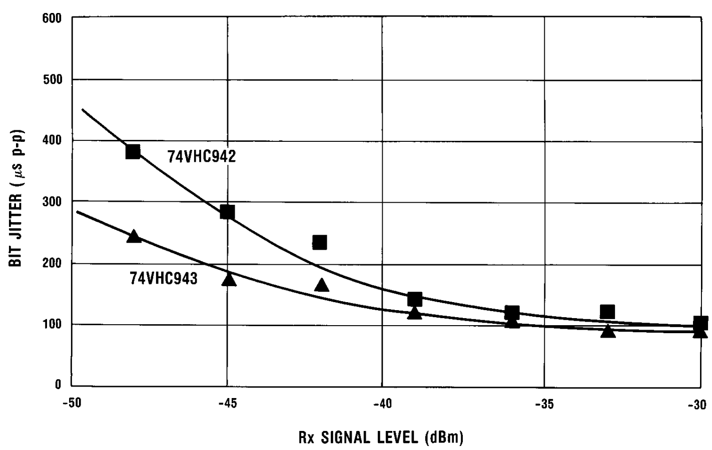

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FIGURE 11. Jitter vs RX Signal (Answer Mode)

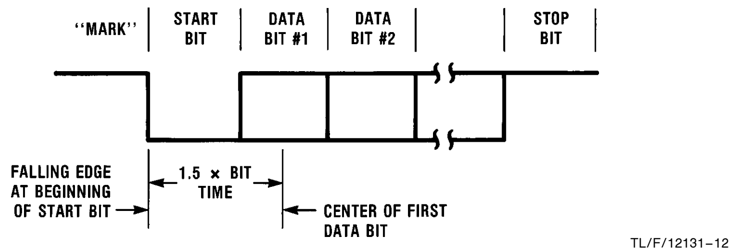

FIGURE 12. Serial Data Input to UART

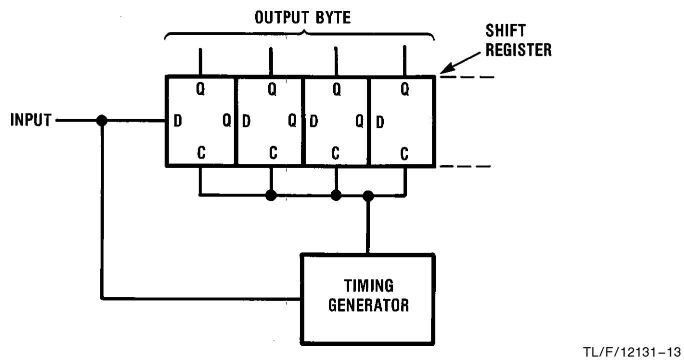

FIGURE 13. De-Serializing Section on UART

The UART de-serializes data by first synchronizing itself to the incoming sequence. After a long "mark," a falling edge, and then a period of "space" occurs. This period is known as the "start bit". The UART starts a timing generator on the falling edge at the beginning of the start bit. From this timing generator the UART can find the ideal times to sample the incoming data, i.e. at the center of each data bit. Each bit is strobed into the shift register at the center of the bit cell as determined by the timing generator. When the entire word has been shifted, the UART returns to waiting for a start bit, and the data in the shift register can be read as a parallel word. Most UARTs do more than this, they also serialize data to be transmitted, perform parity generation, insertion and validation, I/O control and many other functions. However these extra functions do not provide insight into the modem to UART interface, so are not discussed here.

Bit bias and jitter are important to modems because they are forms of distortion which may interfere with the ability of the UART to de-serialize the incoming data. Bias and jitter alter the timing relations between the edges of an incoming word. If an output data edge moves with respect to the start bit, the UART may sample the demodulator output at the wrong time, and an error may result.

There are several ways in which bias, jitter and inter-bit distortion can interfere with the UART. Jitter affects the UART at both the synchronization at the start bit and at the data sampling. Jitter at the start bit causes all the UART samples to be offset from the center of the data bits. This reduces the amount a data edge can move before an error occurs. Inter-bit distortion can aggravate this situation. The modem in its "wait" state is at a perpetual mark. This is the condition under which inter-bit distortion shows itself. Inter-bit distortion will thus shorten the length of the start bit. This can be aggravated by a modem showing marking bias. The start bit can become so short that the UART fails to synchronize on it. This can cause catastrophic failure of the system, as it can cause complete breakdown of the modem to UART interface. This phenomenon may be reduced by lengthening the start bit to 1.5 or 2 bit times (possible options on many UARTs). Thus this breakdown may be start bit length sensitive.

A further variable that affects the modem to UART interface is the resolution of the UART. Some UARTs operate the timing generator at 8 times the baud rate, some use a factor of 16 or more. The finite resolution introduces quantization error which is worse for the UART operating at the lower factor.

DYNAMIC RANGE

Dynamic Range, like most modem specifications, is very definition sensitive. In general it refers to the range of received signals for which the modem operates. However a definition of "operation" must be found. A suitable definition would be "capable of receiving 1000 bits without an error".

Maximum received signal is usually the limit at which the receiver of the modem is overloaded. A modem which is always connected to a Bell system will receive a maximum signal of −12 dBm, as this is a Bell specification. This is the reason for the maximum receive signal specification of −12 dBm on the 74VHC942/943 integrated circuits. On the other hand, a modem which is to be operated in a non-Bell system may be expected to operate with larger signals than this. So in designing a modem system it may be necessary to add gain or attenuation at the interface to the phone line so the maximum signal presented to the modem internal circuitry does not exceed manufacturer's recommendations.

It is difficult to measure the maximum signal at which a modem will operate. The mechanism of overload in a modem is highly design sensitive, and results from a complex interaction between the hybrid, the phone line, and the modem's receive filter. This analysis is well beyond the scope of this application note. Many modems will, on the bench, exceed their specification. It is still unwise to operate a modem at a level exceeding the manufacturer's specification, as these designs may fail to operate under some conditions.

Minimum received signal is usually the signal at which the modem begins to make errors in the absence of noise. This may be measured using the circuit of *Figure 1*. The signal is progressively attenuated until the data analyzer begins to record errors. This breakdown of performance is often abrupt; the modem may make no errors at one signal strength, and make only errors when the signal is reduced a further 1 dB.

A modem's dynamic range is often sensitive to the operating mode. Many modems operate to a lower signal level if their transmitter is squelched, or if the transmitter is sending no data but is running, than if the transmitter is sending data. The 74VHC942/943 work to approximately −46 dBm in full duplex mode, and often work to −53 dBm in half duplex operation. The parts are specified to −40 dBm in full duplex conditions and −48 dBm in half duplex conditions.

As noise can cause a modem to make errors when there is good signal strength, dynamic range measurements are always made in the absence of noise. Dynamic range can occasionally be phone line sensitive so conditions should again be specified.

MODEM FILTER SPECIFICATIONS

Some modem manufacturers provide data on their receive filter designs. This data is of more interest to modem designers than modem users.

The "receive filter gain error" refers to the flatness of the receive filter characteristic. It is generally measured between the "mark" and "space" frequencies. As modems transmit data as the frequency of the tone, amplitude errors generally have little effect on performance. The only place this specification may be observed to have effect is in carrier detect circuits. As these circuits follow the receive filter, a filter gain error will cause the trip points to shift depending on the tone transmitted.

The receive filter group delay distortion refers to the group delay difference between the mark and space frequencies. Group delay refers to the time energy takes to pass through a filter. Thus group delay error causes the "mark" energy and the "space" energy to take different times to propagate through the receive filter. As is illustrated in *Figure 14* this causes data to become scrambled, as the period at the data change either has neither mark nor space energy, or has both.

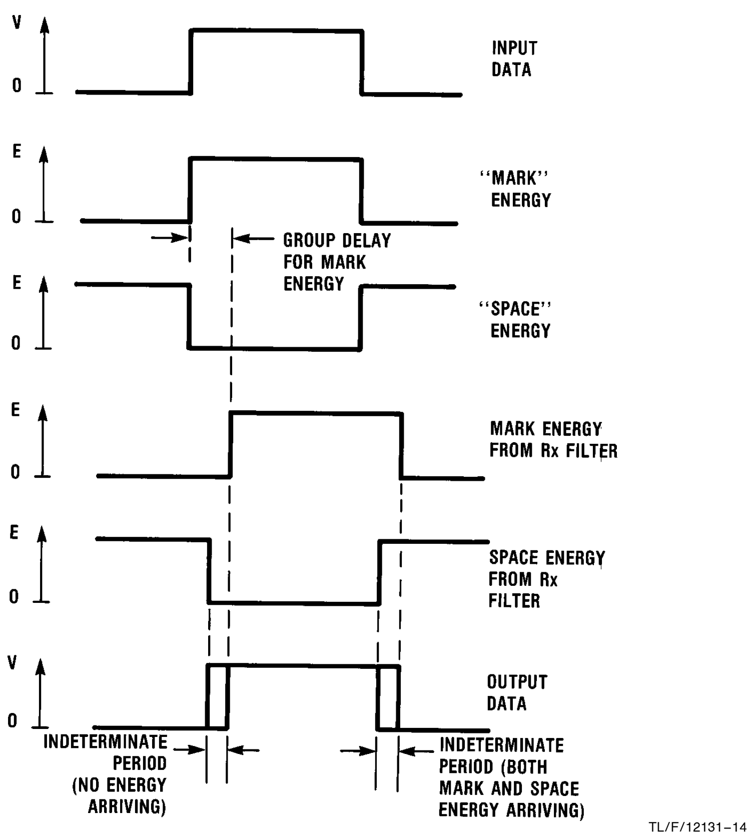

FIGURE 14. Affect of Group Delay on FSK Signals

The main effect of group delay distortion is an increase in bit jitter. This in turn will show up in bit error rate measurements. Group delay distortion does not have as strong an effect on performance as other aspects of modem design, and for this reason is often of little interest, particularly if bit error rates and bit jitter specifications are available.

Note that group delay of the entire system consists of the sum of the group delay of the transmitter, phone line and receive filter. As the group delay of the phone line varies from one line to another there is a lower limit to this distortion which can be achieved. Many modems which do not have the receive filter output available do not specify this parameter.

TRANSMITTER SPECIFICATIONS

Transmitter specifications are usually fairly simple to interpret, but there are some small traps for the unwary.

The second harmonic of the transmitter is more important for some tones than for others. The second harmonic of the originate mode space tone (1070 Hz) falls in the middle of the band in which the originate modem is receiving. This is thus the most important tone for a second harmonic specification. The originate mode mark tone (1270) has a second harmonic outside the band in which the modem is receiving, but it is near enough to this band to have a small effect. The second harmonics of the answer band transmitted tones are both above 4 kHz, and thus only constitute ''out of band noise''. Many modems thus have their answer band second harmonic specified by the out of band noise requirements.

Out of band noise should meet the Federal Communications Commission (F.C.C.) Specifications. This allows the modem design to meet the F.C.C. requirements without external filtering. However, as most modem designs couple to the phone line through a transformer having limited high frequency response, the noise above about 1 MHz is usually irrelevant.

Modem transmitters, if of poor design, can contribute to bit jitter and thus to isochronous distortion. This may occur due to a variety of mechanisms. However, for 300 Baud modems the modulator design task is not difficult, and most commercial designs contribute little distortion in their transmitter. Thus few manufacturers specify this parameter.

CARRIER DETECT TRIP POINTS

Carrier detect trip points are measured by adjusting the level of the standard modem output until the carrier detect output of the MUT responds, indicating either receipt of, or loss of carrier. The signal levels at which these occur indicate the carrier detect trip points. These trip points are usually centered about −45 dBm and are thus very difficult to measure, as a small amount of noise in the test system can considerably effect the result.

The conditions under which carrier detect levels should be measured are difficult to define. As is determined by the handshake protocol, the originating modem waits for carrier with its transmitter squelched, while the answer modem waits for carrier with its transmitter running. If the carrier level drops during data transmission, the carrier detect circuit may register loss of carrier and interrupt transmission. In this case the loss of carrier has occurred while each modem has been transmitting data. Carrier detect levels often change slightly depending on the exact condition of the modem when they are measured. Thus attempting to specify them accurately can be difficult.

The carrier detect circuit provides some indication that the signal strength is acceptable for modem operation so trip points should be reasonably predictable. The presence of carrier is not, however, a complete assurance that there is another modem on the line (the circuit may trip on noise or speech), or that data present is of acceptable quality (modem performance is often a stronger function of S.N.R. than of signal level, and the carrier detect circuit measures signal level, not S.N.R.).

Some modems, e.g. ''dumb'' stand alone modems, have only the carrier detect circuit to provide information on the quality of the data being received. For these modems the carrier detect trip point should indicate loss of carrier at the lower limit of the modem's dynamic range. Note that this dynamic range will depend on the operating conditions of the modem, so an adjustable carrier detect trip point is an advantage, allowing the user to optimize the carrier detect trip point for the application.

Some ''smart'' modems can use more sophisticated data validation techniques than simply measuring the carrier level. For example if the modem has a UART, and the UART has a parity error flag, the modem can directly assess the bit error rate of the line, and judge the line depending on the data quality.

It is thus difficult to assess what constitutes ''acceptable'' carrier detect operation, as this depends strongly on the modem application.

A non-flat receive filter can cause the carrier detect trip point to be mode and tone dependent. This variation contributes to the modem mode dependence discussed above.

BIT ERROR RATE MEASUREMENTS

The bit error rate of a modem is usually measured using the setup of *Figure 1*. The data generator #1 generates a long pseudo-random binary (PRB) data stream. The data analyzer receives the data from the modem under test, and compares the received data to the transmitted data to detect and count errors as they occur. The bit error rate (B.E.R.) of a modem is a measure of the rate at which errors occur in the data being transmitted through the modem/phone line/modem transmission path.

Most modems produce no errors if they are operating within their dynamic range, and if no noise is present. Thus B.E.R. is a measure of the modem's ability to correctly demodulate data in the presence of noise.

Bit error rates are the real test of modem performance. When a user is sending data, the bit bias, bit jitter and all other parameters are irrelevant, as long as data is being transferred reliably. Bit jitter and bit bias are useful for quick analysis of modem performance, and they somewhat reflect bit error rate (B.E.R.) performance. Measuring B.E.R. is a time consuming process, and the final results reflect the test setup as much as the modem. Before B.E.R. measurements can be compared, the conditions of measurement must be carefully studied.

SYNCHRONOUS OR ASYNCHRONOUS OPERATION

The B.E.R. of a modem will vary depending on whether the system has a synchronous or asynchronous system for the serial to parallel conversion following demodulation.

A typical configuration for a synchronous data analyzer is shown in *Figure 15*. The delay is adjusted and the data from the modem is sampled at the center of each bit cell. The EXOR gate will produce a logic 1 if the modem's output is different from the reference data. The errors may then be simply counted at the flip flop's Q output. Note that in most modem systems using a UART, the data clock is not available.

Systems using a UART must synchronize the data rate clock from the falling edge at the beginning of the start bit, and thus distortion of this edge will adversely affect the ability of the UART to accurately de-serialize the data. Performance is thus not as good as the case of synchronous operation. Thus measuring a modem with synchronous data will not give meaningful data on how the modem will operate with a UART (asynchronous data). As most 300 Baud modems operate with a UART, this test configuration (i.e. asynchronous operation) is the most meaningful way to evaluate them.

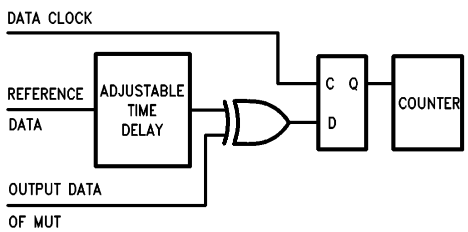

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FIGURE 15. Synchronous Data Analyzer

When testing with a UART the word length, parity, start and stop bit length need to be defined. These have less effect on modem performance than noise measurement or deserialization technique.

BIT ERROR RATE AND BLOCK ERROR RATE

Modem specifications vary as to the method of specifying bit errors. If the modem is operating with a UART a noise burst may cause the UART to synchronize incorrectly, causing an entire byte or frame to be received incorrectly. Conversely, multiple bit errors within a byte of data usually only invalidate that single byte. This may be of little significance to the user as many communication protocols require retransmission of the entire block if an error is detected. Some manufacturers thus specify their modems in terms of block error rate rather than bit error rate. This is rare, however.

FURTHER VARIABLES IN MODEM EVALUATION

As is implied by dynamic range specifications, signal amplitude can affect modem performance. This can result from several phenomena. A modem's receive filter has limited dynamic range, with its lower limit set by the filter's noise floor. Thus reducing the signal will affect the S.N.R. at the demodulator, although the S.N.R. at the phone line may remain unaltered. Signal amplitude may also affect modem performance as the hard limiter or A.G.C. (Automatic Gain Control) circuits in the receive path generally have limited dynamic range.

In summary, many variations of configuration can affect modem performance measurements. Unless test conditions are accurately specified the results are virtually meaningless.

Bit error rate measurements were made on the 74VHC943 monolithic 300 Baud modem. The conditions under which they were made is summarized in Table I. These conditions accurately reflect the conditions under which the modem is designed to operate, and are all relevant to the test results.

TABLE I

BIT ERROR RATE MEASUREMENT CONDITIONS

Parameter	Condition
Noise Bandwidth:	C-Weighted
Data Format:	Asynchronous 8 Bit words Even Parity One Start Bit
Data Pattern	511 Bit pseudo-random
Phone Line Simulation	Resistive line
Counted Errors:	All data bits
UART Clock Rate	16 * Data Rate
Standard Modem (transmitter)	Identical to M.U.T.
MUT Transmitter	Transmitting 300 Baud PRB Data
MUT Transmitter Amplitude	Set for "permissive" characteristics

DISCUSSION OF BIT ERROR RATE CURVES

The results of these bit error rate measurements are shown in *Figure 16.* From these curves the signal to noise ratio for a bit error rate of 1.0E-5 can be interpolated. (This is a common value to specify.) It is 3.5 dB in answer mode and 5 dB in originate mode. Note the degree to which the measured points diverge from the curves. This is due to the statistical nature of the test and due to the difficulty of measuring noise using a digital volt meter.

Several different line simulators were tried and bit error rate measurements made for a fixed signal to noise of 3.4 dB. They were 4.7E-5 for a resistive line, 4.3E-5 for an average line, and 4.87E-5 for a worst case line. These measurements differ by less than the accuracy of the test system, indicating the minimal effect of the phone line on the overall system.

SOME MANUFACTURERS OF MODEM TEST EQUIPMENT

(This list is by no means comprehensive.)

Phoenix Microsystems, Inc.
8290 Whitesburg Drive South
P.O. Box 4206
Huntsville, AL 35802

Comstron Corporation
200 East Sunrise Highway
Freeport
N.Y. 11520

Hewlett Packard Corporation
1820 Embarcadero Rd
Palo Alto
CA 94303

FURTHER READING

(1) Data Sheets for 74VHC942 and 74VHC943 Monolithic 300 Baud Modems, National Semiconductor Corp.

(2) "Transmission Parameters Affecting Voiceband Data Transmission—Measuring Techniques" Bell System Data Communications Technical Reference, May '75.

(3) "Data Communications Using Voiceband Private Line Channels" Bell System Technical Reference, Pub 41004, Oct., 73.

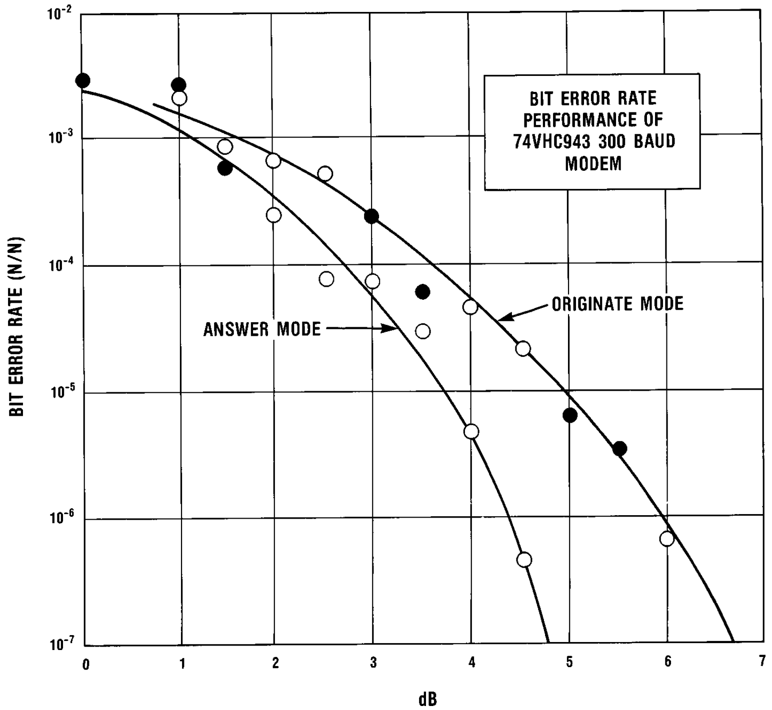

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FIGURE 16. Bit Error Rate Performance of 74VHC943 300 Baud Modem

(4) "Data Communications Using the Switched Telecommunications Network" Bell System Data Communications Technical Reference, May '71.

(5) "Use and Evaluation of VA300 (Bell 103A Type) Data Sets" Application Note No. 1, The Vadic Corporation, 916 Commercial, Palo Alto, CA.

(6) "CMOS 300 Baud Modem" National Semiconductor Application Note #1014 (Reprinted from Midcon/82).

(7) "Physical and Transmission Characteristics of Customer Loop Plant" *P.A. Gresh* Bell Syst Tech J., Dec. '69.

(8) "Signal Quality at Interface Between Data Terminal Equipment and Synchronous Data Circuit-Terminating Equipment for Serial Data Transmission" E.I.A. Standard RS-334-A, Engineering Department, Electronic Industries Association, Aug. '81.

(9) "Data Transmission" *Bennet, Davey* McGraw Hill, 1965.

(10) "Comparison Report of MM74HC942, MM74HC943 versus TMS99532" National Semiconductor Corp, Sept. 1983.

(11) "74VHC942 and 74VHC943 Design Guide" National Semiconductor Application Note 1016.

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