GTE LENKURT

DEMODULATOR

DECEMBER 1972

Phase Jitter

Until recently, phase jitter was little more than a definition to the communications industry. Since phase jitter did not cause errors in voice or low-speed data communications, there was little need for a comprehensive understanding of the subject. But, with high-speed digital transmission, phase jitter as slight as 1° may cause errors in the reception of the bit stream.

Transmission engineers have been aware of the existence of phase jitter for some time, but since it has little effect on voice intelligibility, it was not considered a significant measure of telephone channel performance. Today with the expanding use of the telephone network for the transmission of high-speed digital signals and the increased use of pulse code modulation (PCM), phase jitter, or time jitter, has become a channel performance parameter of increasing concern. The transmission channel has not changed but phase jitter is more deleterious to high-speed signals than to voice signals with their redundant nature (only about 25% of a voice signal is needed for intelligibility).

As transmission speeds increase, data pulses become narrower and closer together. Eventually, these pulses become so close together that phase jitter can displace a pulse enough that the receiving equipment "sees" a pulse where it should see a space, or vice versa. Digital transmission is sensitive to phase or time jitter regardless of the modulation technique used — phase, frequency, or amplitude. Consequently, jitter is now a matter of increasing importance to the equipment designer, transmission systems engineer, and data systems user.

In recognition of phase jitter's increased significance, transmission performance objectives and measurement standards have been set by a number of groups such as D.C.A. (Defense Communications Association), Bell System, and E.I.A. (Electronic Industries Association). It is particularly important that the definition and measurement of phase jitter be thoroughly understood by the designer, engineer, user, and technician in the light of its increased importance in the telecommunications field.

In high-speed digital transmission, phase jitter is used to describe the change in periodicity that results during transmission. And, time jitter refers to synchronization errors on PCM transmission systems.

Phase jitter on data transmission systems has been traditionally defined as unwanted change in phase or frequency of the transmitted signal due to modulation by another signal during transmission. Using this definition, if a single-frequency test-tone is frequency or phase modulated during transmission, the received tone will have sidebands associated with it (a single-frequency is used for testing and measuring phase jitter). The amplitude of these sidebands, compared to the received tone, is a measure of the phase jitter imparted to the signal during transmission (see Figure 1). This phase jitter can be the result of intersymbol interference (distortion caused by the tails of preceding and

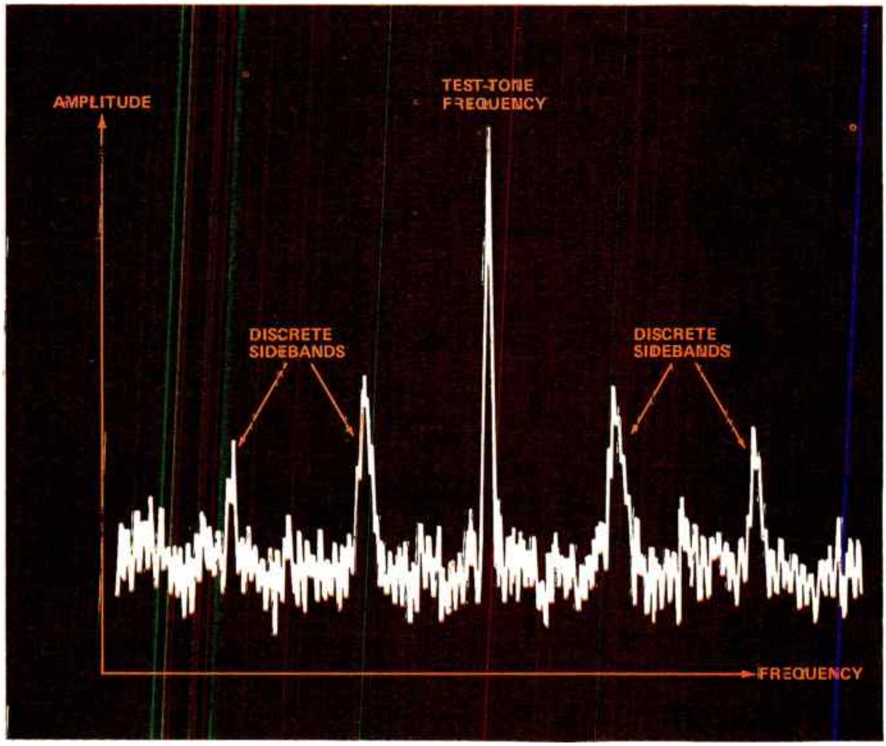

Figure 1. When testing for phase jitter, a single-frequency test-tone may appear to have a definite spectral distribution such as symmetric, discrete sidebands or it can have random, low-amplitude sidebands like noise.

succeeding pulses into the time slot of the pulse currently being transmitted) or crosstalk (interference caused by energy being coupled from one circuit to another). Phase jitter is measured in degrees of peak-to-peak variation for each cycle of the transmitted signal. And, time jitter is measured in seconds of variation for each sampling period.

The definition of phase jitter as a modulation process specifies its characteristics and distinguishes it from the amplitude/phase variations caused by other forms of distortion such as spurious signals, crosstalk, impulse noise, and channel noise.

Phase jitter can also be defined as *any* unwanted variations in the zero crossings (when the transmitted signal returns to zero amplitude) of the received signal. Data modems look at zero crossings so this is an easy characteristic to measure. Figure 2 illustrates how the zero crossings can vary on a digital signal that has phase jitter.

In a carrier channel, if a single-frequency test-tone is modulated by a second pure tone, sidebands are generated at the carrier frequency plus and minus the modulating frequency of this second tone. The effect of these sidebands depends on the modulation process. If the sidebands amplitude modulate the transmitted signal, the signal amplitude varies, but its phase is not affected by the sidebands. There-

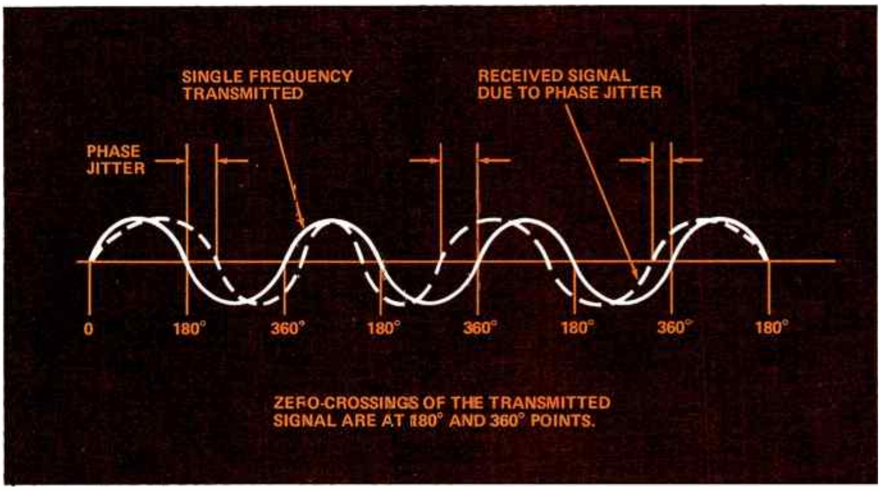

Figure 2. Phase jitter varies the zero crossings of the received signal.

fore, the periodicity of the carrier's zero crossings is unaffected and no phase jitter is produced. During phase modulation, the amplitude of the modulated wave remains constant, while the phase varies with the amplitude of the modulating signal. With phase modulation, the sidebands are always 90° out of phase with the transmitted signal and will therefore phase modulate the signal, changing the periodicity of the carrier's zero crossings – causing phase jitter.

A single interfering tone can produce both angle modulation and amplitude modulation. Each additional interfering tone acts not only on the carrier, but on each of the other tones as well. Many such interfering tones spaced at random frequencies approximate white noise. Therefore, noise and other types of interference are inextricably tied in with any jitter measurement.

Sources

The modulation process that causes phase jitter may be either phase or frequency modulation depending on the source which is generally in the terminal equipment and not generated on the line. It generates symmetrical sideband components spaced at the jitter frequencies (the transmitted frequency plus and minus the frequency of the modulating signal), and the amount of jitter is a function of the magnitude of the jitter source and not a function of the frequency or level of the transmitted signal.

Undesired incidental phase modulation of digital signals is of the most concern for those signals transmitted over carrier circuits. In multiplex units, phase jitter results from incidental phase modulation of the oscillators used for the translation of the signals within the channel to a different part of the spectrum for transmission. This incidental phase modulation is caused by noise, and line-related ripple on office batteries and on power and bias supplies, and within timing circuits on FDM systems. This modulation is transferred to the multiplexed signal during frequency translations and generally, the greater the number of translations on a circuit, the greater the phase jitter. Therefore, the signals transmitted over channels in the higher supergroups have the most phase jitter.

Measurements have indicated that for long-haul, multiple-link systems, the most serious components of incidental phase modulation are power-line related, both as harmonics of the line frequency as well as fractions of the line frequency. With an individual carrier system, the predominant components of the phase modulated signal are low-frequency, time-varying signals, which are quite often related to noise occuring on office power supplies.

Thus, phase jitter most commonly occurs at rates related to the power-line frequency (60 Hz) and its harmonics and submultiples, the telephone ringing frequency (20 Hz), and the interaction between these two sources. Modulation components above 300 Hz rarely occur, if they do, they are accompanied by large amounts of jitter below 300 Hz.

Although phase jitter principally occurs in carrier equipment, it may also be caused by automatic equalizers and associated equipment.

Additive Signals

The effect of channel noise, typical of the undesired parameters that the channel adds to the test tone, is distributed throughout the circuit bandwidth. These additive signals cause simultaneous variations in both amplitude and phase. This occurs whenever two or more signals are added. These amplitude/phase variations are completely related and either may be measured to completely describe the parameter. The amplitude variations are more easily measured, and these additive signals are typically described in terms of their levels – noise level, distortion level, or spurious tone level.

The only parameter which varies just the signal phase is angle modulation. It is this incidental angle modulation (which includes both phase and frequency modulation) that is defined as phase jitter. The magnitude of the signal-correlated noise is a function of the signal level, the signal-to-noise ratio therefore remains essentially constant when the test tone level is varied. For this reason, jitter readings typically show little change for a large variation in test-tone level.

Extensive measurements have been made to determine if phase jitter varies with test-tone frequency. Theoretically, a variation would not be expected as the phase jitter originates on the carrier supply oscillators and is then uniformly transferred onto the signals in the channel during frequency translations. Variations which do exist have been shown to be caused by the modulation of the jitter sideband structure, by the channel amplitude and envelope delay characteristics and by the additive effects of crosstalk, spurious tones, and unequal noise distributions which result in a variation of the additive signal effects as the test-tone frequency is varied.

Measurements made at the standard test-tone frequency represent channel behavior and provide standardization of measurement, utilize existing test-tone generators and eliminate variations in readings due to channel effects not related to phase jitter.

Phase Jitter Measurement

Phase jitter measurements are made by transmitting a single-frequency tone on the circuit of interest and observing the frequency distribution of the received signal. The standard test-tone frequency is 1020 Hz (1000 Hz is no longer used since it is a submultiple of the 8000-Hz sampling frequency of PCM systems).

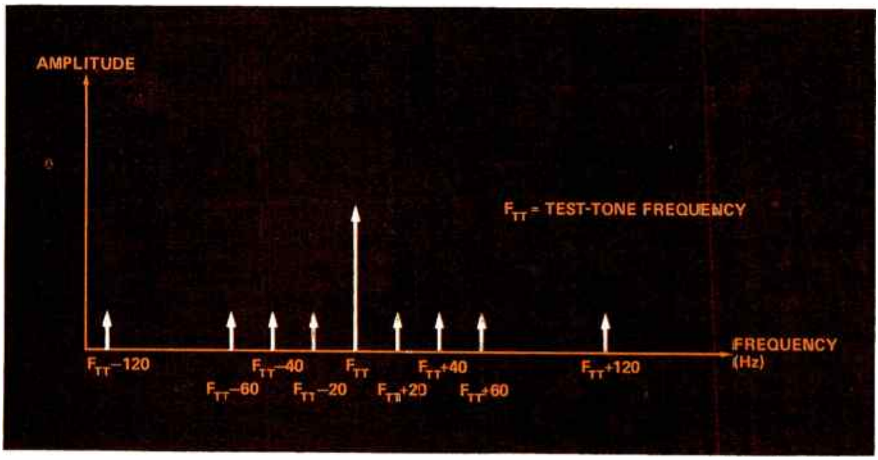

Figure 3. Phase jitter caused by power-line frequencies and telephone ringing frequencies have a definite spectral distribution.

The frequency distribution of phase jitter is shown in Figure 3. The sideband structure shown is similar to that of an amplitude modulated carrier, and differs only in the phase relationships between the carrier and its sidebands. Thus, the measurement technique used must be able to differentiate between amplitude and angle modulation.

There are several methods of measuring phase jitter. The oscilloscope method provides a real and meaningful measurement in the lab, however, it is not necessarily suitable for field measurements. The oscilloscope must have performance capabilities which are commensurate with a good lab oscilloscope and may not always be found in the type of scope used in the field. In addition, relatively unskilled personnel would most likely find the use of the scope and resultant interpretation of the peak-to-peak readings difficult.

Another technique makes use of the measurement of the carrier-to-sideband level, then relates the measurement to peak-to-peak phase jitter via a chart. This is perhaps a more convenient and conventional measurement that is made throughout the telephone industry. Although the equipment used is complex and expensive, it is more familiar in the telecommunications field.

Still another technique involves the use of two test tones and has the advantage of considerable operational simplicity for the technician making the measurement. This technique has the possible disadvantage that a special generator must be provided, while the other techniques use standard readily available test signals.

A more convenient measurement technique uses zero-crossing detectors to check for disturbances in the periodicity of the received signal. There are many factors that cause unwanted zero crossing variations. The measurement technique used must give some indication as to the jitter source causing this variation. Unless this source information is given, there is little to be gained by making the measurement.

The frequency distribution of the jitter components is an important characteristic which permits at least

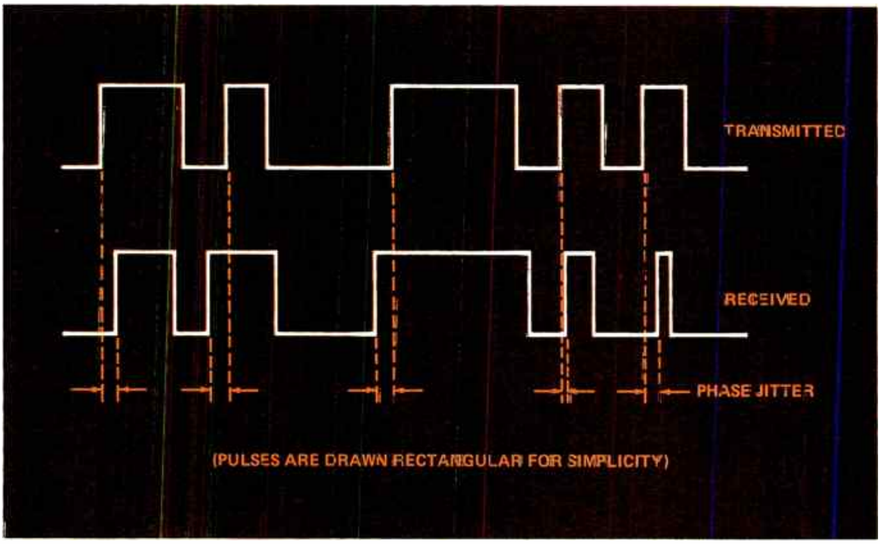

Figure 4. Phase jitter causes the received digital pulses to change in duration and can cause errors when translating pulses and spaces at the receiving end.

one type of jitter to be distinguished from another. The traditional hum modulation caused by power-supply ripple is relatively easy to identify since it nearly always produces jitter components that fall within 20-300 Hz of the single-frequency tone used for testing and measuring phase jitter. Other jitter sources produce components that are generally distributed throughout the circuit bandwidth.

PCM Systems

Hum modulation is not the source of jitter on PCM systems, but noise, near-end crosstalk (NEXT), and intersymbol interference are the major causes of PCM time jitter. Signal distortion in PCM transmission results from many factors – sampling, quantizing, and compandor mistracking – all of which can be referred to as constant power distortion.

In contrast to the measurement of phase jitter, a small change in the test-tone frequency can make a substantial change in the distortion spectrum when measuring jitter on a PCM system. Time jitter is frequency dependent. As the test-tone frequency is changed, the jitter changes in both magnitude and spectral distribution. However, time jitter is independent of the level of the test tone.

Time jitter can be minimized through careful equipment design and system engineering. A given time displacement has a greater effect on the shorter period of high-frequency signals (see Figure 4). Thus, time jitter becomes more critical with increasingly higher bit speeds.

Minimization

In designing digital transmission equipment, care should be taken to select coding methods, modulation techniques and other parameters that will minimize the effects of phase jitter.

GTE LENKURT
1105 COUNTY ROAD
SAN CARLOS, CALIFORNIA 94070

ADDRESS CORRECTION REQUESTED

Bulk Rate
U. S. Postage
PAID
San Carlos, Ca.
Permit No. 37

MR. R. H. GLEICH 165
MILWAUKEE RR CO.
MILWAUKEE ROAD, DEPOT
SAVANNA, ILLINOIS 61074

Just printed, this 32-page **TELECOMMUNICATIONS PRODUCTS CATALOG** has a description and photograph of every GTE Lenkurt product. For your copy, write today to GTE Lenkurt, Department C134.

GTE LENKURT

VIDEO, VOICE & DATA
TRANSMISSION SYSTEMS

The GTE Lenkurt Demodulator is circulated monthly to selected technicians, engineers and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions.