The Lenkurt
JULY 1968
DEMODULATOR

DATA LOADING FOR MILITARY COMMUNICATIONS

Military communications must operate within unique requirements – including data loading different than CCIR and CCITT.

The impact of data and other forms of digital transmission on the modern communications system is increasing steadily. The demand for data circuits is, in fact, growing at a greater rate than for voice channels – especially in the military. This tug-of-war between data and voice has for the moment produced an interesting but solvable problem for the military system designer.

In the military communication networks, such as AUTOSEVOCOM, AUTODIN, and AUTOVON, where the signals are composed largely of digital forms, the problem becomes more complex for the system and design engineer. The critical point revolves around the FDM multiplexing/FM radio equipment, originally engineered for analog voice, but now called on to carry a higher percentage of digital signals at higher levels than originally designed. Because of this, a great deal of attention is being focused on the interrelation of data levels, loading, and noise performance in multichannel systems, especially those using microwave radio relay.

Loading

Loading, or load capacity, of a communications system may be defined as the volume of traffic that can be handled without exceeding the calculated distortion or noise originally designed into each link of the network. The actual physical makeup of the individual parts of a system determines the maximum load which the end-to-end system can handle. Load capacity, in terms of voice traffic, is traditionally (and realistically) measured on the basis of the probable load at the time of heaviest traffic – hence, the telephone term, busy hour.

Multichannel systems were typically designed to carry a specified number of voice channels during the busy hour, and at a load value derived from statistical evaluations. Loading has, in the past, been based on the equivalent load for a given number of voice channels. The formulas give the level of white noise that would be necessary to simulate the loading of a given number of channels. The equivalent load (P), expressed in dBm0 is:

$$P = -1 + 4 \log N \text{ (12-240 channels)}$$

$$P = -15 + 10 \log N \text{ (more than 240 channels)}$$

where

N is the number of channels.

Systems designed on these formulas are adequate if they are to carry only voice, or voice with a small percentage of data signals at a level higher than –15 dBm0 per channel. At –15 dBm0, voice and data can be mixed indiscriminately with no limitations.

The statistical properties of groups of tones used for data transmission are essentially identical to those of voice when the numbers are large. This is

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illustrated in Figure 1. If data is placed on the system in such a manner that the combined power of the data tones occupying a channel does not exceed −15 dBm0, the loading on the system will be essentially the same whether the channels are used for data or voice.

Unfortunately, −15 dBm0 is a rather low level for data transmission, especially in military applications. Restricting the data power to this level seriously affects the signal-to-noise ratio. It is for this reason that it is necessary to operate data at considerably higher levels, typically in the range of −8 dBm0 to −10 dBm0, and in some instances, as high as −5 dBm0. It is obvious that these are considerably higher than the −15 dBm0 average power level in a voice signal. Common data levels are shown in Figure 2.

Another factor to consider is that data is transmitted as a series of tones and presents a continuous load. Of specific interest are the levels at which these tones are presented and the relationship of the peak power signal to the power of the voice signal which it replaces. Consequently, as more and more channels of a system are shifted from voice to data, the total signal power – and, hence, the loading of the system – will increase.

System Noise

Noise in any form obscures the signal and causes transmission errors.

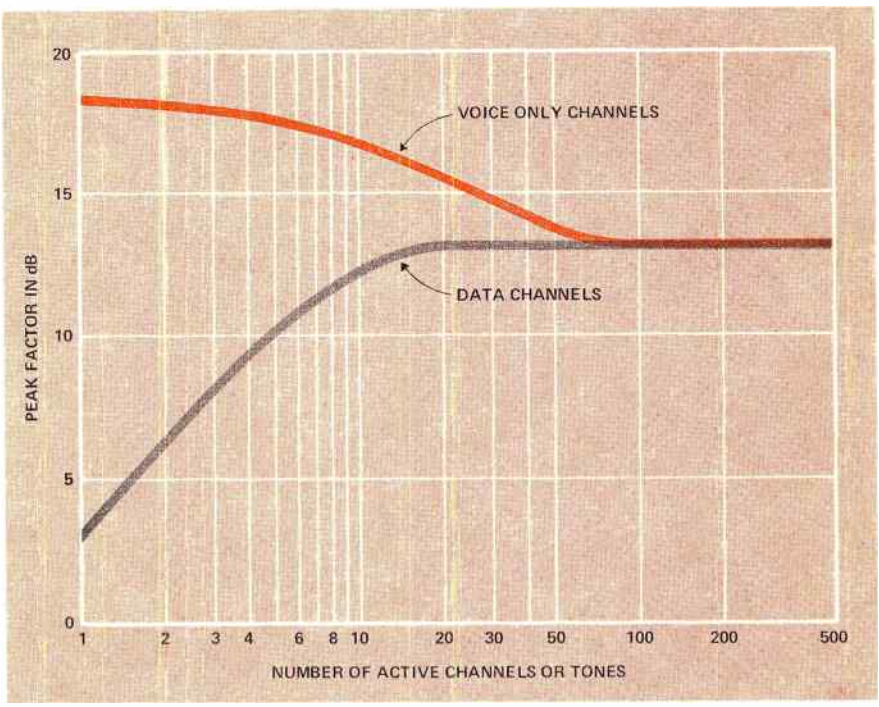

Figure 1. The patterns for the two peak factors – peak to rms ratios – of data and voice are essentially the same when the number of channels is large. However, restricting data to low levels affects signal-to-noise ratios.

	CCITT	U.S.
HIGH SPEED DATA	−10 dBm0 simplex −13 dBm0 duplex	−10 dBm0 switched − 8 dBm0 private line (− 5 dBm0 occasionally)
MEDIUM SPEED DATA		− 8 dBm0 total power
TELEGRAPH SPEED DATA		− 8 dBm0 total power
12 or less	−19.5 dBm0 each (−8.7 dBm0 total)	
18 or less	−21.25 dBm0 each (−8.7 dBm0 total)	
24 or less	−22.5 dBm0 each (−8.7 dBm0 total)	
PHOTOTELEGRAPH (FAX)	−10 dBm0 for FM 0 dBm0 absolute power for DSB−AM	− 8 dBm0

Figure 2. Commonly used levels for data applied to a voice channel.

Although noise is constantly introduced into the communications channel from the transmission medium and the equipment itself, it can be overcome by suitable design.

Actually, the amount of noise present is not as important as the relative strengths of the signal and the noise – the greater the signal-to-noise ratio, the better and clearer the transmission.

Within a communication system there are two basic types of noise: idle noise and intermodulation noise. Idle noise, present in the system at all times despite the absence of modulation, has accumulated a number of other names, among them are thermal noise and residual noise. This noise is basically in the electronics equipment itself and is of the random or "white noise" type. Idle noise varies inversely with receive input level, or signal level, while intermodulation noise varies with system loading.

Intermodulation noise is the result of nonlinearities in the equipment through which the signal must pass, and is a direct result of increasing the signal load. In an FM microwave radio, increased operating levels cause increased frequency deviation. More intermodulation noise is the result, although this is an effective method of decreasing some of the idle noise. While the highest level possible would be desirable in increasing the signal-to-noise ratio, a certain tradeoff must be made. As intermodulation noise increases, its effect is felt slowly at first. Then a "break point" is reached and it increases very rapidly. Near this level the optimum exists.

If the fixed amount of permissible deviation is shared by only a few channels, the signal-to-noise ratio in each channel will be quite good. As the number of channels is increased, intermodulation noise limitations demand that the per-channel frequency deviation be reduced, with a consequent increase in idle noise.

For a given system bandwidth, loading, and RF signal level, the per-channel deviation can be determined which will provide the best balance between idle noise and intermoduation noise. Beyond this, if the loading is increased, a different optimum deviation would apply, unless some other factor is also changed. Figure 3 illustrates the compromise necessary.

Effect on Equipment

Many segments of the communications network are affected by data loading, each in its own way. In the "hard wire" portion of the data systems – the path between the data modem and the multiplex equipment – the signal is at voice frequency as it travels through office cabling, line extensions and switches. Here, the signal is often subjected to high ambient noise levels, particularly the impulse type of noise which is very destructive to data though completely insignificant to voice operation.

There is also a rather strong threshold effect with data. Noise a few dB below the data determining level (i.e. mark or space) goes unnoticed. But, as it reaches this level, the noise will immediately result in data errors.

Most other noise, including intermodulation products in multichannel systems, is random and affects both voice and data. However, the effect of an increase or decrease in this kind of noise is far more dramatic on data than on voice. For example, an increase of only 1 dB in the signal-to-noise ratio provides a theoretical ten-fold improvement in the data error rate. But, a 1-dB change is barely detectible in voice transmission.

To combat this type noise, the system designer may call for higher levels to improve the signal-to-noise ratio. There is nothing to overload in the "hard wire" region and crosstalk into other channels is about the only limitation on the level used for data.

Within the multiplexing process there are several stages involved. Channels are frequency translated to create groups, then supergroups, and then the line signal. The multiplex is the point where sharing of common equipment first comes into play. It is the vital stage at which relative values of data and voice power must be established.

It is important to note that once the relative values of voice and data are established at the input to the multiplex section, they cannot be changed throughout the rest of the system.

Voice vs. Data

Actually, the signal-to-noise ratio in good, modern communications systems is usually far in excess of what is needed for reliable voice communications. The subjective desire of the customer for added ease and convenience, rather than greater intelligibility, is good cause for commercial service to be offered with less noise.

In looking at how data loading affects the communications system, each segment needs to be treated separately. One portion is that part of the transmission system where the signal is in the baseband form. Included are the multiplex line equipment, the interconnecting cables, and the baseband portion of the microwave equipment. In this region the inputs, output and all intervening items are dedicated fixed circuitry. With proper design, no limitations on the relationship of voice and data are imposed.

In the hard wire and multiplex areas there are valid reasons for maintaining a relatively high data level with respect to voice. It is in this area that the bulk of impulse noise exists. Furthermore, it is not necessary to incur any technical penalty in these segments in order to allow data to be handled at a higher level.

In all of these areas, the data signal can be kept at relatively high levels, providing the multiplex equipment is designed for heavy power loading.

An important segment to be considered is the microwave radio system, where some natural limitations of a kind that do not exist in other parts of the system come into play. The signal is transmitted by FM, accomplishing a bandwidth-for-noise tradeoff. But while the medium itself does not impose any severe bandwidth restriction, a finite amount of spectrum is available – and this can be an obvious limitation.

The load carrying capabilities of a particular microwave system are a complex function of a number of factors, including system bandwidth, per channel deviation, RF signal level, and others.

Most of the complexities arise in this area, with two conditions pulling in opposite directions. It is desirable to keep the FM deviation high so that the signal level is well above that of idle noise. This is closely tied with the need to have adequate signal even during very deep fades. But, increasing the deviation causes intermodulation noise to increase.

Possible Solutions

There are several solutions available to the systems engineer when adding sizable percentages of data channels at

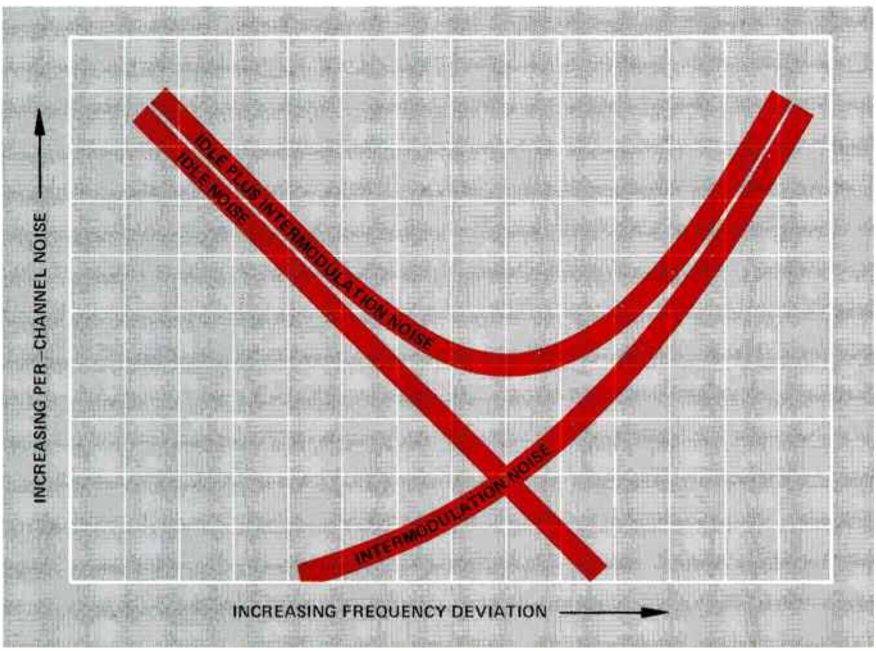

Figure 3. Idle noise is reduced in direct proportion to an increase in frequency deviation. But beyond a certain point peculiar to the equipment, the increasing intermodulation noise rapidly overcomes and reverses this advantage.

higher levels. The most obvious is to remove the equivalent number of voice channels for each data channel according to power load. For example, one –5 dBm0 data channel would require the removal of ten voice channels. While this is surely a workable answer, it becomes self-defeating – 30 data channels would use up the entire capacity of a 300-channel CCIR system.

A related and more widely accepted approach is to sharply limit the percentage of data channels and distribute them through the system so that no item of common equipment will be overloaded.

Another possibility is to drop data levels down nearer the equivalent voice channel load and juggle the total loading to provide an acceptable level of performance.

One solution centers on equipment design rather than operation procedure, and requires a multiplexer and radio capable of carrying higher loadings. This is the approach used in the AN/UCC–4, developed and manufactured by Lenkurt for the military. It will accept data levels as high as –5 dBm0 on all channels simultaneously. This capability allows complete freedom in assignment of channels that can be used for data, and almost no restrictions as to relative voice and data levels.

Military Loading

The Defense Communications Agency, realizing the effect of loading on the Defense Communications System, recently recommended certain revisions to the microwave standards of DCAC 330–175–1. DCA felt these changes were necessary to provide improved microwave equipments and subsystems of the DCS to support the DCA worldwide wideband transmission improvement program.

The recommendation for loading as suggested by DCA is:

$$P = -1 + 4 \log N \text{ (12-32 channels)}$$

$$P = -10 + 10 \log N \text{ (32-600 channels)}$$

The equivalent noise power for 600 channels under military loading is +17.8 dBm0. This is considerably above the recommended CCIR loading level – in fact, it corresponds more closely with the CCIR system designed for 1850 channels. Thus, it is obvious that the time-accepted CCIR loading formulas no longer apply to military systems.

Design Approach

Increasing the loading capability of the radio to achieve the acceptance of larger numbers of high level data signals is possible. This is the approach taken by Lenkurt in the design of the 75C microwave radio for military applications. Together with the AN/UCC–4 multiplexer the 75C offers a versatile communications package.

The impact of data on communications – especially on the DCS network – is forcing a critical look at operational standards and systems design. Loading formulas have changed to more accurately reflect the military communications environment, and improved transmission systems must meet today's needs while matching the design criteria of the future.

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