The Lenkurt® Demodulator

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NOISE PERFORMANCE in Industrial Microwave Systems

Part Two

This is the second part of a two-part article by Robert F. White, Lenkurt Transmission Engineer. The first part, which discussed such factors as noise sources, thresholds, loading, and noise-specifying methods, appeared last month.

The term, "noise power ratio," which came into the language with the advent of white noise testing methods, has had a certain vogue as a somehow more "fundamental" quantity than the signal-to-noise ratio in the voice channel. However noise power ratio is only an intermediate step in a particular method of making noise-loaded measurements. The most modern noise loading test sets do not even use this step but go directly to the significant end-result, noise in the channel. For a given set of measuring conditions, a correcting factor can be calculated which, when added to the noise power ratio, will give the signal-to-noise ratio, but this factor is not always the same. So a given noise power ratio sometimes means one thing, sometimes another. The fairly common practice of specifying noise performance both ways — as a noise power ratio and as a signal-to-noise ratio or noise power in the voice channel — is particularly undesirable. It gives results which are either redundant if they come out the same or contradictory if they do not.

Lenkurt's practice is to specify and calculate microwave system noise performance in dba0, F1A weighted. The end result is usually given both in dba0 and in signal-to-noise ratio. Conversion from one to the other, or to other noise units, is easily made. Figure 1 correlates signal-to-noise ratio, dba, and picowatts for noise which is essentially random, and Figure 2 gives dba versus picowatts in graphical form.

Column 1 in Figure 1 gives flat signal-to-noise ratio in a 3-kc voice band; column 2 gives the equivalent in dba, F1A weighted, in a 3-kc voice band; and column 3 gives the equivalent in psophometrically-weighted picowatts.

The table is applicable to signal-to-noise ratio conversion only if the noise is of the random, or "white noise" type. The dba/picowatt conversion is based on the following correlation which was established by Bell System and British Post Office engineers in connection with the transatlantic cables — it is valid for any kind of noise:

$$dba = -6 + 10 \log_{10} pw_p$$

System Noise

Despite the complexity of the problem, it turns out that it is necessary to define, calculate and measure only three significant parameters in order to determine with adequate precision the limits of noise performance which a microwave system will have under actual operating conditions, even taking into account the effects both of fading and busy hour loading.

These parameters are:

1. The receiver input level at which the noise in the worst derived voice channel reaches 52 dba0.
2. The required fade margin in db. This affects the noise performance since it determines what the receiver median input level (corresponding to the non-faded condition) must be. Adding the fade margin to the threshold level gives the median input level.
3. The noise in the worst derived

S/N	dba0	pw_p0	S/N	dba0	pw_p0	S/N	dba0	pw_p0
28	54	1,000,000	48	34	10,000	68	14	100.0
29	53	794,000	49	33	7,940	69	13	79.4
30	52	631,000	50	32	6,310	70	12	63.1
31	51	502,000	51	31	5,020	71	11	50.2
32	50	398,000	52	30	3,980	72	10	39.8
33	49	316,000	53	29	3,160	73	9	31.6
34	48	252,000	54	28	2,520	74	8	25.2
35	47	200,000	55	27	2,000	75	7	20.0
36	46	159,000	56	26	1,590	76	6	15.9
37	45	126,000	57	25	1,260	77	5	12.6
38	44	100,000	58	24	1,000	78	4	10.0
39	43	79,400	59	23	794	79	3	7.9
40	42	63,100	60	22	631	80	2	6.3
41	41	50,200	61	21	502	81	1	5.0
42	40	39,800	62	20	398	82	0	4.0
43	39	31,600	63	19	316	83	−1	3.0
44	38	25,200	64	18	252	84	−2	2.5
45	37	20,000	65	17	200	85	−3	2.0
46	36	15,900	66	16	159	86	−4	1.6
47	35	12,600	67	15	126	87	−5	1.3
48	34	10,000	68	14	100	88	−6	1.0

Figure 1. Comparison of noise performance units: flat signal-to-noise ratio in a 3-kc band; dba0, F1A weighted; and psophometrically weighted picowatts.

voice channel with median input level to the receiver (or receivers if it is a multihop system), measured with the radio baseband loaded with white noise power equivalent to the busy hour load for full rated channel capacity of the system.

For the purposes of this article, the first two parameters can be disposed of rather simply. There is nothing very controversial about the choice of 52 dba0 as the point at which a voice channel should be taken out of service, even though the channel would still be usable at even higher noise levels. But for present day requirements, 52 dba0 is a quite reasonable figure for determining the threshold. The choice of a figure for fade margin is considerably more complex but not really controversial either. There is no question that fade margins at microwave frequencies must be high, the only question is *how* high. The decision is a familiar one: economics versus reliability. In the 6-Gc band, which at the present time is the "work horse" for the industry, fade margins are now almost always at least 35 db and often as high as 45 db or more on "problem" paths; 40 db is a quite typical value easily achievable with conventional microwave equipment and antenna sizes. System reliability is not the subject of this article and it has been brought into the discussion only because it affects the choice of fade margin and fade margin affects noise performance.

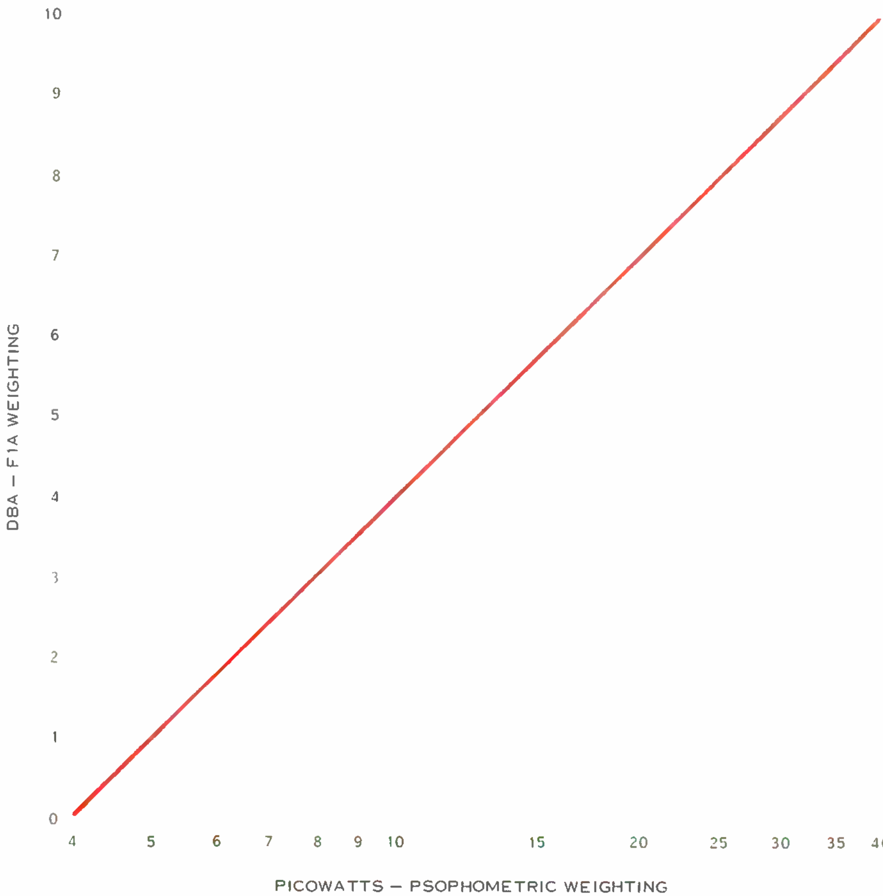
These two parameters, threshold and fade margin, are characteristics of the individual hops rather than of the system. Their measurement is simple and straightforward. It is done in the field only to determine whether the equipment is operating properly and whether the receiver input level is at or very near the value which has previously been calculated for the path.

All the rest of this article will be devoted to a discussion of the third parameter, which is perhaps the most basic one, since it is the one which describes the day-in, day-out noise performance of the system. Threshold noise occurs only for fleeting instants and at very rare intervals, but *this* noise is there all the time (though it may drop a db or so during non-busy periods).

A most important contributor to this noise parameter is intermodulation distortion. The importance of intermodulation characteristics in determining the load handling capability of a microwave system has not always been fully appreciated. Until a few years ago, there was no convenient way of calculating or measuring loaded performance, and microwave systems were often judged on the basis of idle noise alone, which could be a very inadequate way of judging true performance.

Now there is a suitable way of measuring loaded performance. The discovery a few years ago that the statistical properties of a multichannel telephone load occupying a given baseband spectrum were very similar to those of a continuous noise load occupying the same spectrum, and the development of noise loading test sets based on this principle, have made it possible to determine with a fairly high degree of accuracy the noise performance of microwave equipment or systems under conditions which are quite similar to those which are encountered in service.

The method allows the microwave noise contribution to be measured separately without reference to the multiplex equipment. Measurements can be made over each hop individually and over the complete system end to end. The microwave system can be measured at its full rated channel capacity, even when it is not equipped initially with a full complement of channels.



$$DBA = -6 + 10 \log_{10} PWP$$

$$PWP = \text{ANTILOG} \frac{DBA + 6}{10}$$

(VALID FOR ANY KIND OF NOISE)

OTHER RANGES:

DBA	PWP
+10	X10
+20	$X10^2$
+30	$X10^3$
+40	$X10^4$
+50	$X10^5$
+60	$X10^6$
+70	$X10^7$
+80	$X10^8$

Figure 2. Curve for converting dba, F1A weighted, to picowatts, psophometrically weighted. The formula on which this curve is based is not limited to white noise, but is valid for any kind of noise.

Noise loading test sets are now readily available, and there is a generally accepted standard for calculating the noise load power to be used:

$(-15 + 10 \log N)$ dbm0, where $N = 240$ or more channels;

$(-1 + 4 \log N)$ dbm0, where N is between 12 and 240 channels.

These formulas include an allowance for the power of signaling tones and a number of telegraph channel tones as well as for the speech currents themselves.

Measuring sets are most readily available for the standardized CCIR microwave channel capabilities of 60, 120, 300, 600, 960, 1800, or 2700 channels. Thus, the third parameter can be measured with considerable accuracy using the proper test equipment — although such equipment is quite expensive.

The Real Objectives

What should the objective be for this most significant noise parameter? This can be an extremely important decision to user and manufacturer alike, since it seriously affects the cost of the system to the user and the technical problems which must be solved by the manufacturer.

Most communications users look to the practices of the telephone industry for guidance in this respect, since telephone people are in the business of selling communications and, consequently, can usually be relied on to look for a good balance between performance and cost. Telephone practice makes a rather sharp distinction between short-haul and long-haul systems, with the dividing point at about 200 miles. For long-haul standards, CCIR and Bell System are the best sources. For the short-haul systems Bell and REA provide good guidelines.

Bell System and CCIR both treat the allowable noise for systems longer than about 200 miles as directly proportional to length, and their standards turn out to be almost identical. CCIR simply allows 3 picowatts per kilometer for the microwave system contribution and 1 picowatt for the carrier contribution, making a total of 4 picowatts per kilometer for the complete system. Converting these to miles yields 4.8 picowatts per mile for the microwave alone and 6.4 for the microwave plus multiplex. The Bell System objective of 38 dba0 for 4,000 miles includes multiplex as well as microwave contributions. Thirty-eight dba is equivalent to 25,200 picowatts, which is equal to 6.3 picowatts per mile, as against CCIR's 6.4 picowatts per mile.

If three-fourths of the total noise is allotted as the microwave contribution, as does CCIR, the result is 4.7 picowatts per mile, almost the same as CCIR's 4.8.

For short-haul systems the practice is quite different. Current practice is to specify a single value of noise for such a system regardless of the number of hops. This figure is, at present, 27 dba0 for the microwave plus multiplex noise. This is equivalent to 2,000 picowatts for the microwave plus multiplex noise, or 1,500 picowatts for the microwave alone. This is about 7.5 picowatts per mile for the maximum length system of 200 miles, 15 picowatts per mile for a 100-mile system, and even more for shorter systems.

The 7.5-picowatt-per-mile figure for the most stringent case in short haul systems is 2 db less stringent than the 4.7-picowatt-per-mile long-haul figure.

As far as the microwave equipment designer or system planner is concerned, the important thing to know is not picowatts per mile, but picowatts per hop, since microwave noise power is approximately proportional to the number of hops rather than to the number of miles. So, before it can really be determined how much strain the above-listed objectives put on the microwave system, it is necessary to know, or arbitrarily decide, the length of the average hop. For example, take the long-haul objective of 4.7 picowatts per mile and see what it means to three different engineers:

Mr. "Conservative" figures 25-mile hops and thus gets a requirement of 117.5 picowatts or 14.7 dbaO per hop. He thinks it can be done, but it's pretty rough.

Mr. "Middleroad" figures 30-mile hops and gets a requirement of 141 picowatts or 15.4 dbaO per hop. He isn't too unhappy about it, though he still doesn't think it's a cinch.

Mr. "Optimist" figures 40-mile hops and gets 188.0 picowatts or 16.6 dbaO per hop as the requirement. He just can't understand what those other fellows are worrying about.

Looking at the worst case short-haul requirement of 7.5 picowatts per mile in the same way, Mr. C gets 16.7 dbaO, Mr. M gets 17.4 dbaO, and Mr. O gets 18.6 dbaO as the per-hop requirement. These figures make all of them pretty happy, so it appears that the agonizing decisions about what performance standards to use really lie only in the area of long-haul systems.

Recommendations

Although the microwave system standards established by the telephone industry provide a basis for establishing adequate performance, they stem from needs which do not always apply to industrial users. Consider the following opinions:

1. The distinction between short-haul and long-haul requirements is valid for industrial as well as telephone users. Unless a short-haul system is eventually to become part of a longer system, there is no need to set the standard any higher than 27 dbaO for an eight-hop system, or an average value of some 17 to 18 dbaO per hop. Even this requirement could be relaxed a couple of db and the service would still be perfectly acceptable. Until very recently telephone companies usually used 31 dbaO for such systems — 4 db worse than their present practice.
2. For long-haul service the industrial user faces a more difficult choice, complicated by the fact that he uses the same system for short- and long-haul service, while the telephone companies use separate systems. It is very tempting to simply fall back on the CCIR or Bell long-haul recommendations and accept them without further consideration. After all, these requirements are only 2 db tighter than the short-haul requirements which can be met fairly easily. It turns out that those 2 db of difference push performance into an area which is much closer to the edge of the present state of the art, especially if "Mr. Conservative's" gloomy estimate of average path length is accepted. This can mean a great many thousands of dollars in the initial cost of a system of even moderate length, and also a considerable increase in maintenance costs if the high performance is to be maintained. Thus, it appears that for the industrial user the cost of these 2 db is too high. The 7.5 picowatt per mile figure used for shorter systems seems perfectly adequate for industrial systems of any length. Even for a 4,000-mile system, this would mean only about 38.7 dbaO for the microwave and about 40 dbaO for the microwave plus carrier. That still is a

42-db signal-to-noise ratio, better than that obtained in a call across town in many parts of the world.

3. CCIR and Bell System's long-haul criteria are based on the use of heterodyne or non-demodulating repeaters. If channel dropouts are needed only at widely separated points, the heterodyne repeater is a clear choice over the demodulating repeater using back-to-back terminals because the noise performance can be made somewhat better and level problems are greatly diminished. With recent improvements in the design of back-to-back repeaters the difference in noise performance between the two has been reduced to something on the order of 1 db.

   Industrial microwave systems, unlike those of the telephone companies, are likely to require channel dropping at almost every repeater point. For this kind of service the back-to-back repeater has a very positive advantage, since the full baseband is available at every point.

   At the present state of the art, the 4.7 picowatt per mile criterion for long-haul circuits can probably be met using back-to-back repeaters of the very best modern design, but not without rigid control of a great many variables. The criterion can be met a little easier, but not very much, if heterodyne repeaters are used.

   If the criterion is relaxed to about 7.5 picowatts per mile, the requirements can be met fairly easily with either type of equipment and, in this case, the back-to-back type appears to be the best choice in most cases.

In summary, why not use CCIR and other similar criteria as guides, but not absolute standards, and modify them to suit the particular requirements rather than following them unquestioningly? It may save microwave users a good deal of money with no significant decrease in performance. •

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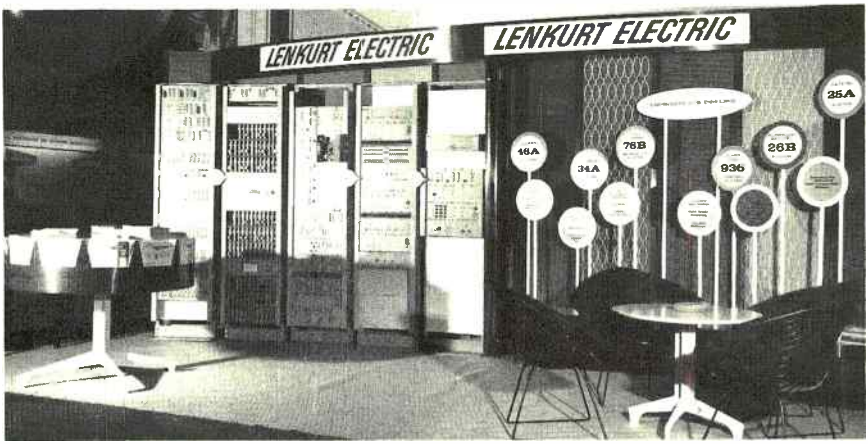

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