BER INSTRUMENTATION MACRO MODULE

ADVANCED MODULES: *ERROR COUNTING UTILITIES, WIDEBAND TRUE RMS METER. Both the system being measured* ***and*** *this macro module require a SEQUENCE GENERATOR.*

introduction

Bit error rate (BER) measurement techniques were first introduced in the experiment entitled *BER in the noisy channel* in this Volume. That experiment used a macro CHANNEL MODEL module. This 'module' was defined earlier in the experiment entitled *The noisy channel model* in Volume D1.

In subsequent experiments this macro module is represented in patching diagrams as a single module, in order to save space.

Likewise, the BER instrumentation is required in many experiments, and it is convenient to represent it also as a single 'macro module' to save space, and repetition, in patching diagrams.

This Chapter is intended to serve as a convenient reference to the macro BER INSTRUMENTATION module.

This instrumentation has been devised for those experiments which use a pseudo random sequence from a SEQUENCE GENERATOR to provide the source message, and a second SEQUENCE GENERATOR in the instrumentation as a reference.

the BER instrumentation

principle

The instrumentation consists of the following elements:

1. a sequence generator identical to that used at the transmitter. It is clocked by the message bit clock. This locally supplied sequence becomes the reference against which to compare the received sequence.
2. a means of aligning the instrumentation sequence generator with the received sequence. A *sliding window correlator* is used. This was introduced in the experiment entitled *Detection with the DECISION MAKER* in this Volume.

3. a means of measuring differences between the received sequence and the reference sequence (after alignment); ie, the errors. The error signal comes from the output of an X-OR gate (the same one used for the sliding window correlator). There is one pulse per error. The counter counts these pulses, over a period set by a gate, which may be left open for 10^n bit clock periods, where n = 3, 4, 5 or 6.
4. a method of measuring the signal-to-noise ratio (SNR) of the signal being examined. The WIDEBAND TRUE RMS METER is ideal for this purpose.

practice

The above ideas are shown modelled in Figure 1 below. It is assumed that the reference sequence generator is identical to, and set up similarly to, that at the transmitter.

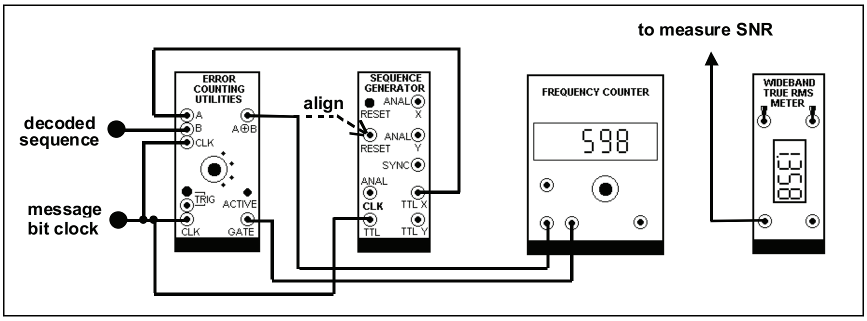

Figure 1: BER measurement instrumentation

In future experiments this model will be represented by the pseudo module shown in Figure 2 below.

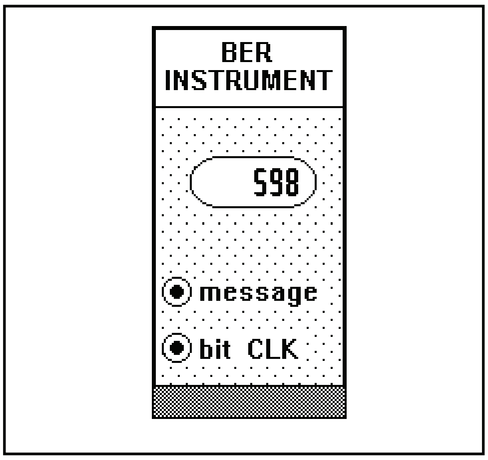

Figure 2: the BER INSTRUMENTATION macro module.

setting up

It is assumed that a transmission system is already in existence.

The procedure for setting up the BER INSTRUMENTATION is as follows:

1. patch up according to Figure 1
2. remove the NOISE from the channel
3. align the two sequences (momentarily connect the reset of the instrumentation SEQUENCE GENERATOR to the output of the X-OR gate of the ERROR COUNTING UTILITIES module).
4. press RESET of the COUNTER. No digits should be displaying.
5. press the TRIG button of the ERROR COUNTING UTILITIES module. The COUNTER should display '1'. This is the 'confidence count', *not* an error count. The COUNTER should remain at '1' for the duration of the PULSE COUNT, verified by the ACTIVE indicator being alight (it flickers during the last 10% of the count period).
6. replace the NOISE at a high level. The COUNTER should start counting bit errors (provided the ACTIVE indicator is alight). Reduce the NOISE and the BER should reduce.

Remember:

- always remove the noise before attempting to align the two sequences.
- the PULSE COUNT indicates the number of bit clock periods for which the GATE remains open (while the ACTIVE indicator is alight), and during which the COUNTER is activated for counting errors.
- the bit error count is the COUNTER display minus '1' (the 'confidence count').
- the ratio (COUNTER DISPLAY - 1) / (PULSE COUNT) is the BER.

theoretical predictions

See your Text book for theoretical predictions of bit error probability of various signals, typically expressed as a function of E_b/N_o, where:

- E_b is the energy per bit
- the only corruption is assumed to be additive white Gaussian noise (AWGN), where N_o is the average noise power per Hz.

From a practical point of view E_b/N_o is interpreted as the signal-to-noise ratio (SNR). This is a power ratio, and is typically expressed in decibels (dB).

The SNR is measured at the decision maker input.

Plots of bit error probability versus E_b/N_o will typically involve the function Q(x), where Q(x) is the complementary error function, given by:

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{u^2}{2}\right) du \qquad \text{........ 1}$$

There are many papers in the literature concerning the evaluation of this integral, including that given by P.O. Börjesson, C-E. Sundberg, "Simple approximations of the error function Q(x) for communications applications", IEEE Trans. Com, Vol. COM-27, No.3, March 1979, p639-643.

The above paper was pointed out to me by my colleague Bob Radzyner, who extracted the following approximation from it.

$$Q(x) = \frac{4f}{\left(3x + \sqrt{(v+8)}\right)} \qquad \text{........ 2}$$

where $f = \frac{1}{\sqrt{2\pi\, e^{v}}}$ 3

and where $v = x^2$ 4

