

DPSK - CARRIER ACQUISITION AND BER

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DPSK - CARRIER ACQUISITION AND BER

ACHIEVEMENTS: *reception and demodulation of a differential phase shift keyed (DPSK) signal, with carrier and bit clock recovery and bit error rate (BER) measurement.*

PREREQUISITES: *completion of the experiment entitled **BER measurement in the noisy channel** (this Volume) is essential; it would be an advantage to have completed the experiments entitled **Carrier acquisition** (this Volume) and **BPSK - binary phase shift keying** (Volume D1).*

ADVANCED MODULES: *NOISE GENERATOR, LINE-CODE DECODER, DECISION MAKER, ERROR COUNTING UTILITIES, BIT CLOCK REGEN, TRUE RMS WIDEBAND METER, DIGITAL UTILITIES.*

EXTRA MODULES: *a total of three MULTIPLIER modules.*

PREPARATION

BPSK

It is essential that you are familiar with setting up a bandlimited noisy channel, and measuring bit error rates (BER) over it. Thus completion of the experiment entitled *BER measurement in the noisy channel* is a prerequisite to this experiment.

It would be helpful, but not essential, if you have completed the experiment entitled *BPSK - binary phase shift keying*, of which the present experiment is an extension.

DPSK

A disadvantage of BPSK is that the receiver requires a knowledge of the frequency and phase of the carrier of the incoming signal.

As for BPSK, DPSK requires a local carrier for successful synchronous demodulation. But the phase of this carrier need not be known. It is the *differential coding* at the transmitter that makes this unnecessary.

experiment outline

The experiment is built around the principles investigated thoroughly in the experiment entitled *BER and the noisy channel*, so only an outline of procedures is given below.

A block diagram of the system to be examined is shown in Figure 1.

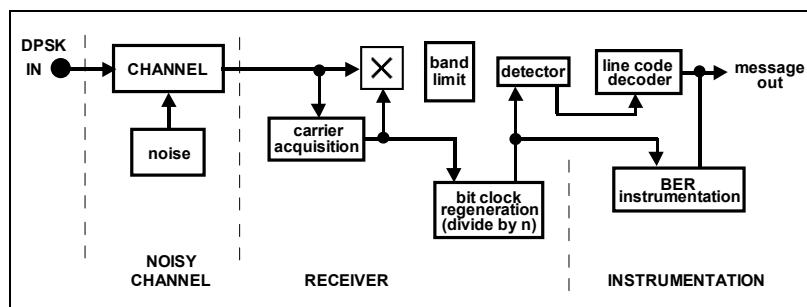


Figure 1: the DPSK receiving system

the transmitter

You will not be concerned with modelling the transmitter. The DPSK signal will come to you via TRUNKS. It will already be bandlimited.

It will be based on a carrier of *exactly* 50 kHz.

The message will be supplied at the transmitter by a SEQUENCE GENERATOR of the type you will have, set to a long sequence. It will be clocked at *exactly* 1/24 of the carrier frequency.

You will be responsible for demodulation and message recovery, both by stolen carrier (from TRUNKS) and by carrier acquisition circuitry.

carrier acquisition

With the data rate a sub-multiple of the carrier frequency then carrier acquisition circuitry is sufficient to recover both the carrier *and* the bit clock.

The method of carrier acquisition to be investigated in this experiment involves a squaring operation, followed by a phase locked loop. It is shown in block diagram form in Figure 2 below. Methods of carrier acquisition (including this one) were examined in the experiment entitled *Carrier acquisition* (in this Volume).

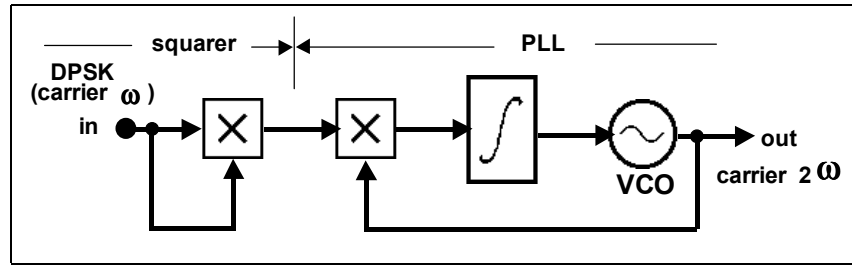


Figure 2: carrier and bit clock acquisition

In the scheme of Figure 2 the squaring operation generates a component at twice the carrier frequency. This is not of constant amplitude. It is smoothed by a phase locked loop, which acts as a narrow band filter.

Digital division-by-two will recover a TTL signal at carrier frequency, and a further division-by-twenty-four the 2.083 kHz clock for the DECISION MAKER.

channel

The channel is the (non-bandlimited) TRUNKS system, followed by an ADDER, which serves as an injection point for the system noise. Noise bandlimiting will occur at baseband. See Tutorial Question Q1.

theoretical predictions

Bit error probability (P_B) is a function of E_n/N_o . For synchronous demodulation of DPSK it has been shown that:

$$P_B = 2Q\left[\sqrt{\frac{2E_b}{N_o}}\right]1 - Q\left[\sqrt{\frac{2E_b}{N_o}}\right] \quad \dots\dots\dots 1$$

The symbols in eqn.(1) are defined in the Chapter entitled *BER instrumentation macro module* (in this Volume).

You will measure not P_B , but BER; and not E_n/N_o , but SNR. Figure 3 shows theoretical predictions, based on eqn(1) above.

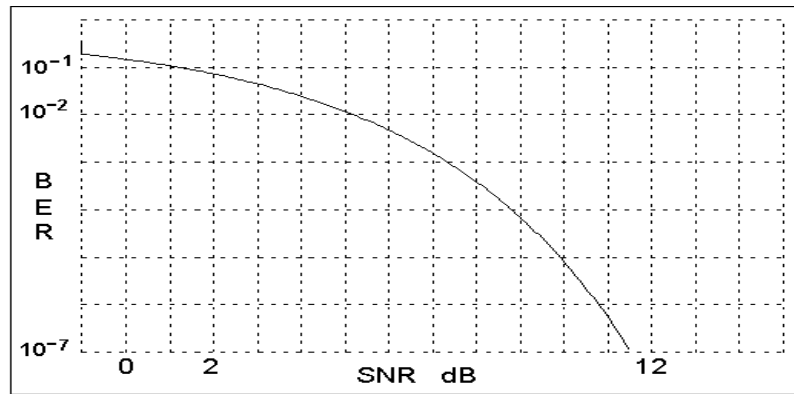


Figure 3: performance prediction - BER v. SNR
(DPSK, coherent detection)

EXPERIMENT

It is expected that you will not be attempting this experiment unless you are an experienced TIMS user. You will have completed the introductory digital experiments, and be familiar with the BER INSTRUMENTATION macro module. It should not be necessary to receive detailed setting up instructions.

This is a big system, requiring more than 12 slots for its modelling. You should plan ahead and decide how to distribute the modules of the receiver, instrumentation, and carrier acquisition models.

receiver

You will be modelling the receiver shown in block diagram form in Figure 1 above, and modelled in Figure 4 below.

T1 before plugging in the DECISION MAKER set the on-board switch SW1 to accept differential encoding (NRZ-M), and SW2 to 'INT' (manual decision point adjustment).

T2 before plugging in the PHASE SHIFTER set the on-board switch to HI.

T3 patch up the receiver. Initially steal the 50 kHz carrier from TRUNKS and the bit clock (2.083 kHz) from the MASTER SIGNALS module. Set the bandwidth the same as that at the transmitter (or wider?).

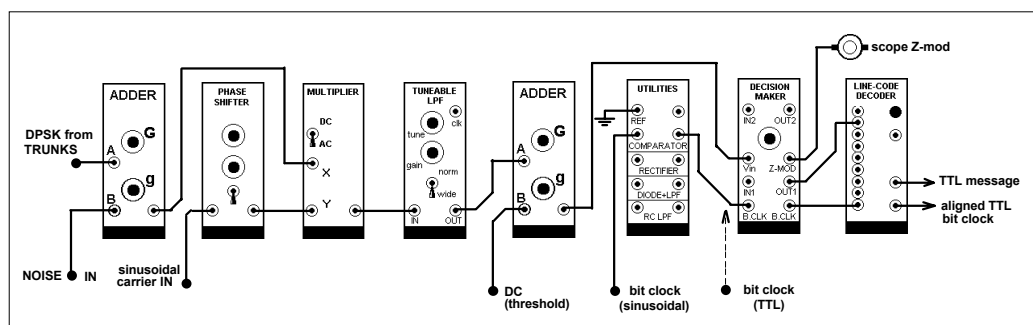


Figure 4: the receiver

T4 set the receiver carrier phase for maximum input to the DECISION MAKER. Then use the channel gain to set this level to about the TIMS ANALOG REFERENCE LEVEL.

T5 set up the oscilloscope for an eye pattern. Set the decision instant to the appropriate part of the eye.

*T6 confirm the received sequence is a (delayed) copy of the sent message.
Confirm the behaviour of differential encoding.*

BER instrumentation

Bit error rate measurements will be made with the model described in the Chapter entitled *BER instrumentation macro module* (in this volume). This is reproduced in Figure 5 below.

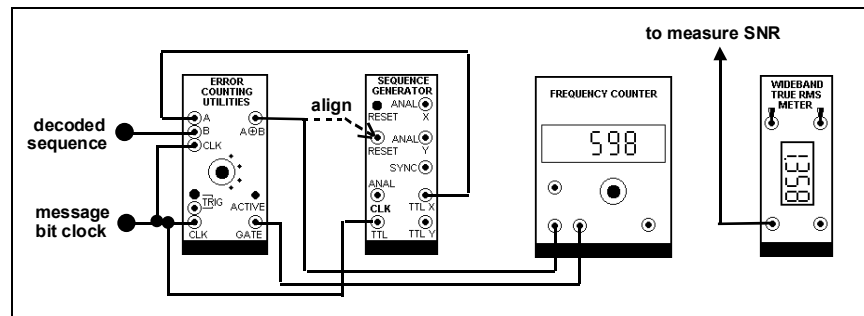


Figure 5: BER measurement instrumentation

T7 set up the instrumentation. Align the received and reference sequences. With no added noise confirm that there are no errors.

T8 add noise. Confirm the error rate worsens as the SNR is reduced.

T9 prepare for some serious quantitative BER measurements.

- a) match the signal to the input threshold of the *DECISION MAKER* (about 25 mV).
- b) add noise into the channel. Set up for a *DECISION MAKER* input SNR of 0 dB, and an absolute level of the *TIMS ANALOG REFERENCE LEVEL*.

BER measurement - stolen carrier

T10 using a stolen carrier and bit clock, make some quantitative measurements over a range of SNR, and confirm that BER matches expectations.

When satisfied that the system is behaving satisfactorily it is time to replace the stolen carrier with one acquired from the received signal.

carrier acquisition

A model of the carrier acquisition scheme shown in block diagram form in Figure 2 is modelled in Figure 6 below.

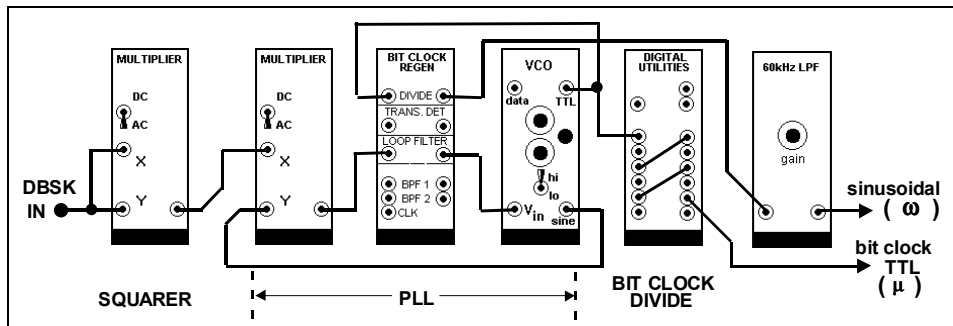


Figure 6: carrier acquisition model of Figure 2

Note that both the MULTIPLIER modules are AC coupled. There should be no component at DC at the input to the first, so AC coupling is merely a precaution against DC offsets. But the output of the squaring process will produce a large DC component, sufficient to overload the second MULTIPLIER, if nothing else. So it should be blocked.

The 100 kHz TTL output from the VCO is divided-by-two with the sub-system in the BIT CLOCK REGEN module (set the on-board switch SW2 with the left toggle UP and the right toggle DOWN). It is then filtered to a sine wave.

There is a TTL signal into an analog module (60 kHz LPF). Whilst this is usually not allowed (in the interests of linearity) here is one of those cases where it is acceptable ! Even if the input stage (of the filter) is overloaded the next filter stage may not be. Provided the output is a sinusoid (have a look) this is acceptable. After all, this is a filter, so it probably will not pass the distortion components anyway. But see Tutorial Question Q2.

bit clock recovery

Division-by-24 is required to derive the 2.083 kHz bit clock from the acquired 50 kHz carrier. This is available in a DIGITAL UTILITIES module.

T11 patch up the carrier acquisition model. Set it up under no-noise conditions. Confirm it is operating as expected.

BER measurement - acquired carrier

- T12** have the system measuring BER with high SNR. Check the carrier amplitude and phase into the receiver MULTIPLIER. Retain the stolen bit clock. Prepare the acquired carrier to have the same amplitude and phase, then use it instead of the stolen carrier. With high SNR there should be no change to measured BER.
- T13** decrease the SNR and observe the deterioration of the BER. Not only is poor SNR to the DECISION MAKER causing errors, but the quality of the recovered carrier will have deteriorated - look for jitter.
- T14** return to conditions of the penultimate Task (high SNR). Change over to the acquired bit clock. It will be necessary to check the alignment of the decision instant using an eye pattern as before.
- T15** measure BER with a high SNR and compare with previous results. Reduce SNR - observe further deterioration of the system BER compared with the stolen carrier condition.

TUTORIAL QUESTIONS

***Q1** noise usually enters the system in the channel. This is at carrier frequency. In the experiment the noise was indeed added into the channel, but it was not bandlimited until it reached baseband. Is this a 'legitimate' experimental technique? What about the 'image response' of the product demodulator - would this cause a problem?*

***Q2** suppose the recovered carrier was not a pure sinewave, because of overload of the filter. What would be some of the consequences?*