FM AND THE SYNCHRONOUS DEMODULATOR

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ACHIEVEMENTS: *confirmation of some properties of the spectrum of an angle modulated (FM) signal; action of a synchronous demodulator on this signal; appreciation of the relative phases between the sidefrequency pairs.*

PREREQUISITES: *familiarity with the contents of the Chapter entitled* ***Analysis of the FM spectrum*** *in this Volume;* *completion of the experiment entitled* ***Product demodulation - synchronous & asynchronous*** *in Volume A1.*

EXTRA MODULES: *SPECTRUM UTILITIES*

PREPARATION

You are going to look at the operation of the synchronous demodulator on the angle modulated signal:

$$y(t) = E.\cos[\omega t + \varphi(t)] \qquad \text{........ 1}$$

For brevity this angle modulated signal will be referred to as being ‘FM’.

synchronous demodulation - linear modulation

In earlier experiments the term ‘synchronous demodulator’ was used to describe the arrangement of Figure 1.

This arrangement (also known as a synchronous product demodulator) has been used to recover the message from AM, DSBSC, and SSB. Since the message was recovered from the modulated signal input in each case, it was not unreasonable to call it a *demodulator*.

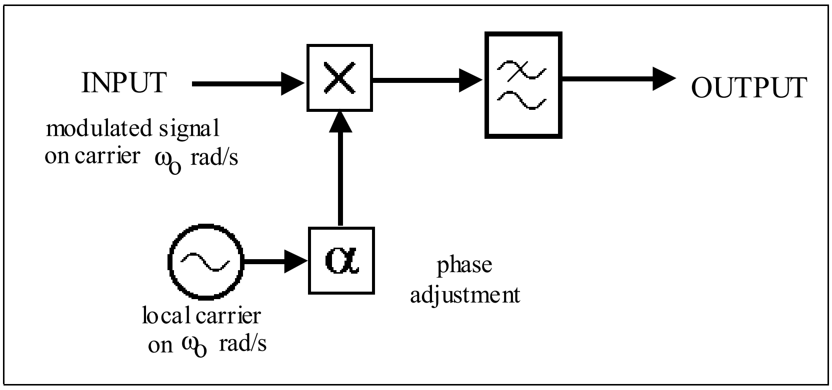

Figure 1: the synchronous demodulator

This was true because these signals were undergoing *linear modulation*. This class of signal was defined in the experiment entitled *DSBSC generation*.

Recall that, for a double sideband signal, as the phase angle α is adjusted, the output amplitude from a synchronous demodulator will vary, including reduction to zero. Zero output results when the local carrier, and the input DSB, are in phase-quadrature.

synchronous demod of non-linear modulation

An FM signal is a member of the class defined as undergoing *non-linear modulation*. These were defined in the chapter entitled *Analysis of the FM spectrum***.**

What will happen when the input to the synchronous demodulator is an FM signal ? Will it recover the message $\varphi(t)$ of eqn.(1) ? The answer is a definite '*no*' ! None-the-less, what happens is of interest, and forms the subject of this experiment.

The arrangement of Figure 1 in this application is best thought of as a *frequency translator*, for the special case where the translation is back to baseband.

FM - spectral properties to be verified

The arrangement illustrated in the above Figure 1 is operating *synchronously* - this means that the incoming and local carriers are on exactly the same frequency. Their relative phases are not yet defined, but may be adjusted by varying the phase angle α .

Remember that the amplitude spectrum of an FM signal, derived from a single tone message, is symmetrical about the central (carrier) term on ω_o. The spectrum consists of pairs of sidefrequencies (DSBSC) alternately in phase-quadrature, and in-phase, with the carrier term. Spectral lines are spaced apart by the message frequency.

From the experiment entitled *Product demodulation - synchronousand asynchronous* you will recall that the upper and lower sidebands of the input signal will be frequency translated down to the baseband (audio) region where their respective contributions will now *overlap* in frequency. The amplitude of the *single* resultant from each *pair* of sidefrequencies will depend upon the relative phases of the two components being combined. These in turn will be determined by the phase angle α.

The 'demodulator' will give an output of many frequency components, one from each of the sidefrequency pairs. These will be on exact harmonics of the original message. The output will thus *not* be a copy of the message.

An FM demodulator would need to (re)combine all the sidefrequencies of an FM signal into a single *component at message frequency. So strictly the arrangement of Figure 1 is* ***not a demodulator*** *in this context.*

Since the pairs of DSBSC in the FM spectrum are alternately in-phase, and in phase-quadrature, their resultants will not maximise simultaneously as the phase angle α is rotated. Thus the amplitudes of odd harmonics of the message will be maximised when the even harmonics fall to zero, and vice versa.

All of the above properties will be verified in the experiment to follow.

You will not make measurements with a WAVE ANALYSER at 100 kHz. You will make baseband measurements to confirm this.

EXPERIMENT

At TRUNKS is an FM signal. It is based on a 100 kHz carrier (of which you have a copy at the MASTER SIGNALS module) and a single tone message near 1 kHz. The frequency deviation is sufficient to ensure several pairs of significant sidefrequencies.

T1 *look at the TRUNKS #1 signal with your oscilloscope. By choice of a sweep speed of, say 1 ms/cm, confirm that its envelope is of constant amplitude, so, if indeed it is modulated, it probably is an FM signal. Use a faster sweep speed and see if you can detect any non-uniformity of the zero-crossings (the compressed and expanded spring analog), thus further confirming the possibility of its being FM.*

FM spectrum determination at baseband

You will use the 'synchronous demodulator' to determine the nature of the FM spectrum. Note that this method makes the measurements at baseband frequencies.

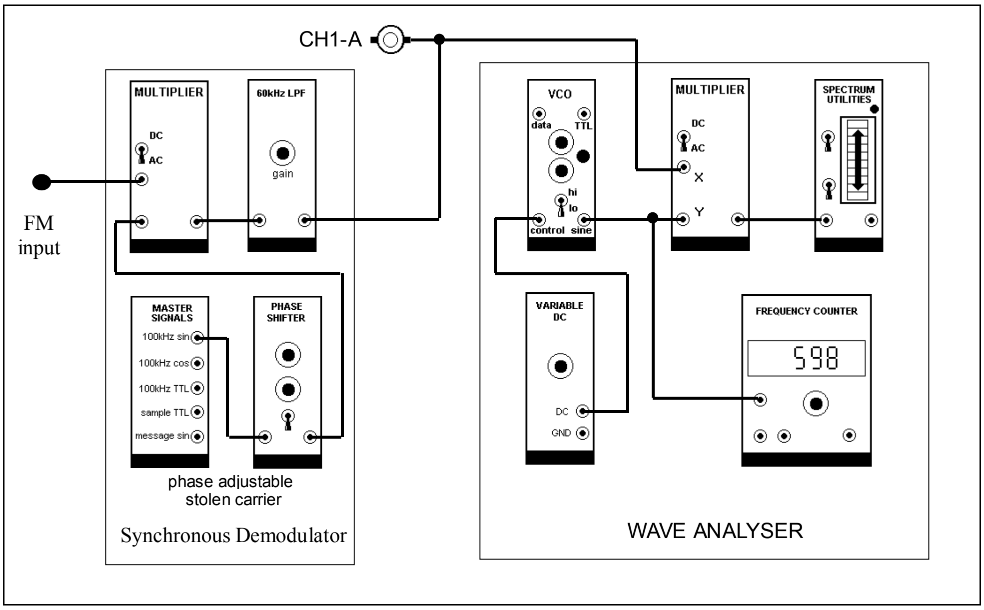

Figure 2: synchronous 'demodulation' of the FM signal.

T2 *patch up the arrangement of Figure 2, which is a 100 kHz SYNCHRONOUS DEMODULATOR and a baseband WAVE ANALYSER. Before plugging in the VCO set the on-board switch to 'VCO'. The front panel frequency range switch will be set to 'LO'.*

You will now have the opportunity to check the observation made in the chapter entitled *Analysis of the FM spectrum* that:

- sidefrequency pairs are alternately in quadrature and in phase with the carrier term at ω.

This means that the first pair of sidefrequencies are in *phase-quadrature* with the carrier.

If the local carrier is set *in-phase* with the received carrier by means of the PHASE SHIFTER then any carrier component present in the FM signal will show up as a DC component at the 'demodulator' filter output.

By maximising the DC output from the filter you are putting the receiver local oscillator in-phase with the received carrier.

Under this condition there will be no output from the odd sidefrequency pairs.

Conversely there will be no output from the even sidefrequency pairs when the carrier is in *phase-quadrature*.

*Thus, **with a little ingenuity**, you can use the WAVE ANALYSER to identify the nature of the spectrum **at 100 kHz**, by making measurements **at audio frequencies**.*

T3 *set the oscilloscope to respond to DC, and adjust the PHASE SHIFTER to maximise the amplitude of the DC output from the 60 kHz LPF. The local carrier is now **in-phase** with the received carrier.*

T4 *use the WAVE ANALYSER to measure the relative amplitudes of all significant components from the 60 kHz LPF. These will be present due to the even-order sidefrequency pairs in the 100 kHz spectrum. Call them V_2, V_4, etc. You cannot measure V_0 (the DC component) since the VCO does not tune down to DC. You could replace the VCO signal with a fixed voltage from the VARIABLE DC module, but if you do this you will need to be sure about what amplitude to use.*

It is now necessary to put the local oscillator into the **phase-quadrature** condition.

T5 *swap from the **sin** to **cos** output of the 100 kHz signal from the MASTER SIGNALS module.*

T6 *use the WAVE ANALYSER to measure the amplitude of all significant components from the filter. These will be present due to the odd-order sidefrequency pairs in the 100 kHz spectrum. Call them V_1, V_3, V_5 etc.*

Make sure you appreciate how you are now in a position to reconstruct the 100 kHz relative amplitude spectrum from the baseband measurements just completed. Do not forget that there is a 'factor-of-two' correction to be applied to the sidefrequencies, but *not* to the carrier [1].

[1] each baseband component came from a sidefrequency *pair*.

T7 *use your baseband measurements to construct an amplitude spectrum of the 100 kHz signal. Compare results with the direct measurement made earlier (or the amplitude spectrum supplied).*

alternative spectrum analysis

The assertion that the sidefrequencies are alternately in-phase and in phase-quadrature can be checked [2] without the aid of the WAVE ANALYSER. Instead use the TUNEABLE LPF at the output of the synchronous demodulator.

This filter can be narrowed to pass only the message frequency at μ rad/s (and DC). By adjusting the phase α the DC output can be maximised, while the AC output (the signal at message frequency) is simultaneously reduced to zero. If the filter is then widened to put the passband edge just above 2μ the component at twice the message frequency will observed at the output, since this component is maximised with the DC.

T8 *use the TUNEABLE LPF in place of the WAVE ANALYSER and isolate separately the DC, the component at μ rad/s, and the component at 2μ rad/s. Record their amplitudes.*

T9 *compare the (relative) amplitudes measured in the previous task with the corresponding results obtained using the baseband WAVE ANALYSER. Comment.*

[2] strictly the check is valid only for the first two pairs.

TUTORIAL QUESTIONS

Q1 *in Task 1, why pick a sweep speed of 1 ms/cm when looking for an envelope ?*

Q2 *would it be of serious consequence if the phase, when transferring from the* **cos** *to* **sin** *outputs of the MASTER SIGNALS module (Task* ***T5****), was a few degrees off a true 90° phase shift ?*

Q3 *for the final Task you were able to isolate the single component at μ rad/s. This is the message frequency. Why could not the SYNCHRONOUS DEMODULATOR, with the filter tuned as it is, then be called an FM demodulator ?*

Q4 *did you confirm that the sidefrequency pairs of the FM signal are alternately in-phase and in phase-quadrature ? Explain.*

Q5 *did you confirm that the sidefrequency pairs of the FM signal are spaced apart by the message frequency ? Explain.*

Q6 *show how the measurements made at baseband were used to determine the amplitude spectrum of the FM signal at 100 kHz. Draw the amplitude spectrum of the FM signal.*

Q7 *the FM signal at TRUNKS is represented by y(t), where:*

$$y(t) = E.\cos[\omega t + \beta \cos\mu t]$$

Can you determine, from the amplitude spectrum of the previous Question, the magnitude of 'β' ?

Q8 *what is the 'factor-of-two' correction which was referred to when mapping from the baseband amplitude spectrum (measured with the synchronous demodulator) to the 100 kHz spectrum ?*