WEAVER`S SSB GENERATOR

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ACHIEVEMENTS: *exposure to Weaver`s SSB generator, and its alignment procedure.*

PREREQUISITES: *completion of some previous experiments involving linear modulated signal generation, especially* ***SSB generation - the phasing method****.*

EXTRA MODULES: *a total of four MULTIPLIERS, two PHASE SHIFTERS, and two TUNEABLE LPF modules is required. This is twice as many of these modules as are in the TIMS Basic Set.*

PREPARATION

principles

You should refer to a Text book for more detail on Weaver`s method of SSB generation [1]. This experiment will introduce you to some of its properties, and methods of alignment.

You are well advised to try the Tutorial Questions (especially Q1) before attempting the experiment, but after reading these preparatory notes..

Weaver`s method of SSB generation, like the phasing method, depends for its operation upon phase cancellation of two DSBSC-like signals. But:

1. it does not require wideband phasing networks, like the phasing method of SSB generation.
2. it does not require sharp cut-off filters, operating away from baseband, as does the filter method of SSB generation.
3. its unwanted components - those which are not fully removed (by phasing, as in the phasing method, or by imperfect filtering, as in the filter method) - do not cause interference to adjacent channels, since they fall *inside* the SSB channel itself.

[1] Weaver, D.K., “A third method of generation and detection of single sideband signals”, *Proc. IRE*, Dec. 1956, pp. 1703-1705

Figure 1 shows a block diagram of the method.

There are two pairs of multipliers. These are referred to as quadrature multipliers, since they use 'carriers' phased relatively at 90^0. This configuration is found in many communications circuits.

The message bandwidth is defined as B Hz. It is shown as extending down to DC, but in practice (speech messages) this is not necessary - even undesirable. The DC requirement would introduce some complications, including the need for the first pair of quadrature multipliers to be DC coupled.

Two filters are required, but they are at baseband, where design and realization is simplified. They must, however, be matched (amplitude and phase responses) as closely as possible.

There are two phase shifters, but they are required to produce a 90^0 phase shift at a single frequency only.

Note that the *second* pair of quadrature multipliers should, ideally, be DC coupled. Think about it ! In practice DC coupling is not often provided, since it introduces DC-offset problems. As a result there can be a small gap in the message, as received, in the vicinity of (B/2) Hz. See Tutorial Question 6.

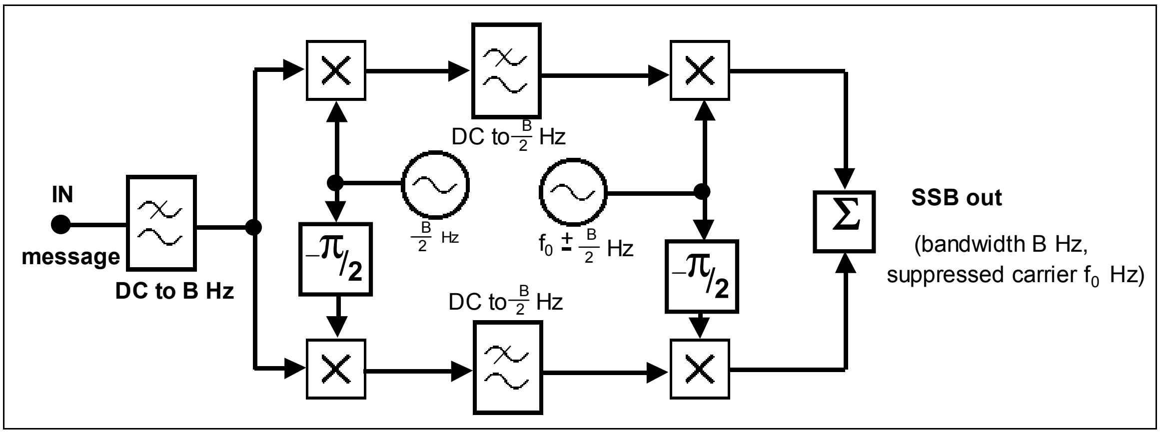

Figure 1: block diagram of Weaver`s SSB generator

Note that the input lowpass filter shown in the block diagram is not included in the patching diagram to follow (Figure 2). Its presence is recognised by not allowing the message source to be tuned above B Hz.

Tracing the message through either the upper arm or the lower arm alone is insufficient to deduce unambiguously what the frequency of the output signal will be. This is because of the cancellations which will take place in the summing block. Until the actual signals and their phases are known it is not possible to deduce which will cancel and which will add.

The analysis can be performed trigonometrically, using a single tone message.

Note that, what ever the output, the carrier frequency is *not* that of the second oscillator.

EXPERIMENT

the model

A suggested model of Weavers SSB generator is shown in Figure 2 below. It is best patched up stage-by-stage, from the input, checking operation until the output is reached.

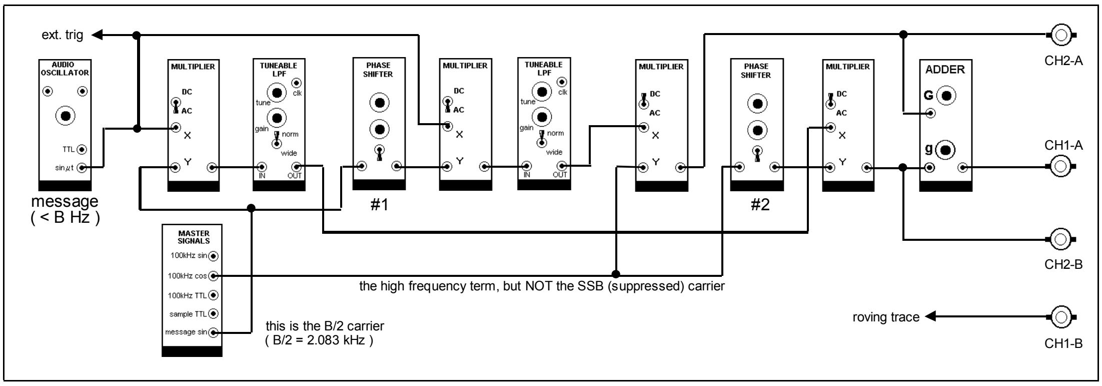

Figure 2: model of Weaver`s SSB generator

Please note: the ‘2 kHz message’ from the MASTER SIGNALS module is not *Weaver`s* message, but is being used as the source of a stable, *low frequency carrier*, on B/2 Hz (refer the block diagram of Figure 1). Thus the message bandwidth must not exceed B Hz. A bandlimiting filter for the message is not included in the model (Figure 2), so the AUDIO OSCILLATOR message source is kept below 4 kHz for correct performance. But you should investigate what happens if this restriction is not adhered to - as it would not be if the message was not strictly bandlimited.

alignment

The alignment of Weaver`s SSB generator is quite straightforward, and will not be given in any great detail.

T1 *before plugging in the PHASE SHIFTER modules, set their on-board range switches; #1 module to ‘LO’, and #2 module to ‘HI’ (refer Figure 2).*

T2 *use the '2 kHz message' from the MASTER SIGNALS module to set the PHASE SHIFTER #1 to about* 90^0*. This is achieved to sufficient accuracy by displaying the input and output to the PHASE SHIFTER on two oscilloscope traces. Adjust the PHASE SHIFTER front panel control until one sinewave is delayed 1/4 period with respect to the other. Fine trimming cannot be carried out until the generator is near completion.*

T3 *set the TUNEABLE LPF modules to the same bandwidth, 'B/2', namely 2.083 kHz. With the front panel switch set to 'NORM', this makes the 'CLK' frequency 2.083 x 880 = 1833 kHz.*

T4 *set the message AUDIO OSCILLATOR to say 1 kHz. Call this* $\boldsymbol{f_m}$ ***Hz****, and make a record of it.*

T5 *now patch up according to Figure 2.*

T6 *trigger the oscilloscope externally to the message on* f_m *Hz. Use the roving trace CH1-B to confirm that the waveforms at the output of each of the low frequency MULTIPLIER modules is a DSBSC. There are no adjustments you can make if this is not so - check patching !*

T7 *trigger the oscilloscope to the 'roving trace' (CH1-B), and use it to confirm that the waveform at the output of each of the TUNEABLE LPF modules is a sine wave. There are no adjustments you can make if this is not so - check patching ! Its frequency will be* $(B/2 - f_m)$ *Hz - confirm this.*

T8 *adjust the gain of each of the TUNEABLE LPF modules filter to make the amplitude of each output sinewave about 4 volt peak-to-peak (TIMS ANALOG REFERENCE LEVEL).*

T9 *confirm with the 'roving trace' that the waveform at the output of each of the high frequency MULTIPLIER modules is a DSBSC. There are no adjustments you can make if this is not so - check patching ! Its 'message' will be the sinewave from the TUNEABLE LPF; use this for external oscilloscope triggering.*

> *When you reach this point all is ready for the final amplitude and phase adjustments, which will achieve the required result at the output of the ADDER.*

T10 *switch the oscilloscope to CH1-A. Remove the patch lead from the* ***upper*** *input of the ADDER. Adjust the* ***lower*** *gain control until the output is a DSBSC of* ***about*** *4 volt peak-to-peak amplitude. Replace the upper patch lead.*

T11 *remove the patch lead from the* ***lower*** *input of the ADDER. Adjust the* ***upper*** *gain control until the output is a DSBSC of* ***about*** *4 volt peak-to-peak amplitude. Replace the lower patch lead.*

You are aiming for an ADDER output of a single sinewave. Although you have adjusted the amplitudes of the signals at the summing point to approximate equality, their relative phases have not been set.

T12 *while watching the ADDER output, vary the phase of the phase shifter #2, aiming for a sinewave.*

T13 *fine trim one (only) of the ADDER gain controls for a better result.*

Remember: a perfect SSB (sinewave message) has a straight line envelope. Synchronise to its 'message' - in this case the output from either TUNEABLE LPF module. Think about it !

Repeat this, and the previous Task, until the best result is achieved.

The two high frequency MULTIPLIER modules, as shown in Figure 2, are set to accept DC. This is a requirement of the Weaver modulator. But in practice it is a problem, since DC offsets, preceding the two high-frequency multipliers, will degrade performance. You can check this by flipping the toggle switches to AC.

T14 *change the input coupling of the two high frequency MULTIPLIER modules to AC, and check if a superior performance can be obtained (a flatter envelope).*

T15 *with the two high frequency MULTIPLIER modules still AC coupled, vary the message frequency through the frequency B/2 (namely, the low frequency carrier frequency of 2.083 kHz) and demonstrate the gap in the response. Message frequencies near 2.083 kHz will be missing. But this imperfection is generally acceptable in practice, and AC coupling is used.*

T16 *is there any point to checking the adjustment of the PHASE SHIFTER #1 ?*

Alignment of the Weaver SSB generator is complete

T17 *measure the frequency of the output. From the details of Figure 1 confirm that this is a possible outcome. What is the carrier frequency ? This means 'with what frequency sinewave would this SSB need to be multiplied to recover the correct message frequency in a convnetional demodulator ?' There will be two answers, only one of which is correct. Which one ? Why ?*

T18 *vary the message frequency over its allowed range of B Hz. Remember there is no message bandlimiting filter installed. Demonstrate that the generator performs satisfactorily over this range (except for the 'gap' previously identified).*

T19 *measure the sideband suppression ratio (SSR). Refer to the experiment entitled* ***SSB generation - the phasing method****, in Volume A1, for details.*

TUTORIAL QUESTIONS

Q1 *perform a trigonometrical analysis of Weaver`s method of SSB generation. Use a single tone for the message. Assume the 'B/2' filters are ideal (and matched). Assume the only impairments are small phase errors α_1 and α_2 in each of the 90^0 phase shifters. Obtain an expression for the sideband suppression ratio in decibels, as a function of these two phase errors.*

Q2 *from a knowledge of the properties of all of the modules you have used, predict from the previous calculation which sideband (upper or lower) your model will generate. Confirm by measurement.*

Q3 *use any method to determine the (suppressed) carrier frequency of the SSB generator, in terms of B and f_o , both defined in Figure 1. Confirm from measurement.*

Q4 *use any method to determine the frequency of the SSB output from the generator, when:*

a) the 'B/2' oscillator is on 2.083 kHz
b) the message frequency is 500 Hz
c) the second oscillator frequency is 100 kHz
d) the phasing resulted in an UPPER sideband.

Confirm by measurement.

Q5 *when the generator was aligned you measured the output frequency. From this single measurement can you state:*

a) if you have an upper or lower sideband ?

This question cannot be answered without

i) knowing something about the internal arrangement of the generator

or

ii) increasing the message frequency, and observing if the sideband frequency increases or decreases.

b) what was the SSB suppressed carrier frequency ?

Q6 *the first pair of quadrature multipliers (Figure 1) need to be DC coupled only if the message contains a DC component. Circuit designers try to avoid DC coupling, as this requires care in minimizing DC offsets. AC coupling is preferred, and this is acceptable for speech. The second pair of quadrature multipliers must be DC coupled, unless one is prepared to accept a small gap in the message (as received) in the region of (B/2) Hz. Explain.*

Q7 *the amplitude of the individual outputs from the ADDER were set to about 4 volts peak-to-peak before final trimming. These were DSBSC-style signals. When they were present together, and the system aligned, about what amplitude would you expect for the final SSB signal ? Show your reasoning. Check by measurement.*