Experiment 3

Objective:

1. Single Sideband AM Generation.

2. Single Sideband AM Reception.

Equipment Required:

1. ST2201 and ST2202 with power supply cord
2. CRO with connecting probe
3. Connecting cords

Theory:

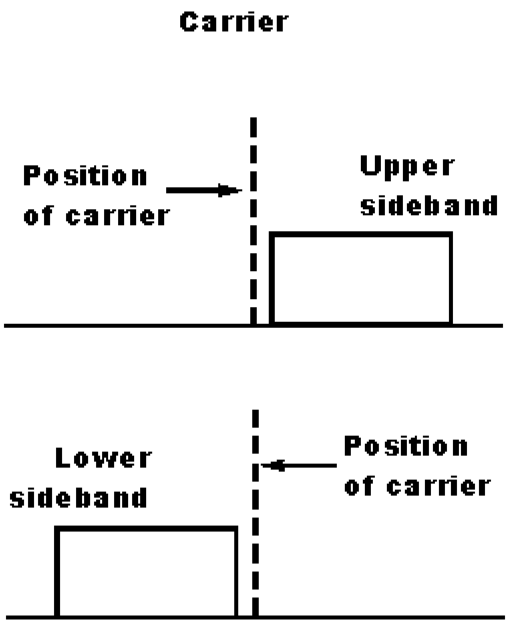
In radio communications, single-sideband modulation (SSB) or single-sideband suppressed-carrier modulation (SSB-SC) is a refinement of amplitude modulation which uses transmitter power and bandwidth more efficiently. Amplitude modulation produces an output signal that has twice the bandwidth of the original baseband signal. Single-sideband modulation avoids this bandwidth doubling, and the power wasted on a carrier, at the cost of increased device complexity and more difficult tuning at the receiver.

Single sideband modulation is a form of amplitude modulation. As the name implies, single sideband, SSB uses only one sideband for a given audio path to provide the final signal.

Single sideband modulation, SSB, provides a considerably more efficient form of communication when compared to ordinary amplitude modulation. It is far more efficient in terms of the radio spectrum used, and also the power used to transmit the signal.

In view of its advantages single sideband modulation has been widely used for many years, providing effective communications, as well as forms being used for some analogue television signals, and some other applications.

A single sideband signal therefore consists of a single sideband, and often no carrier, although the various variants of single sideband are detailed below.



SSB Frequency Spectrum

Figure 1

Single-sideband has the mathematical form of Quadrature Amplitude Modulation (QAM) in the special case where one of the baseband waveforms is derived from the other, instead of being independent messages:

$$s_{\mathrm{ssb}}(t) = s(t) \cdot \cos(2\pi f_0 t) - \widehat{s}(t) \cdot \sin(2\pi f_0 t),$$

where $s(t)$ is the message, $\widehat{s}(t)$ is its Hilbert Transform, and f_0 is the radio carrier frequency

A.Setup for Single Sideband AM Generation.

Procedure :

1. Ensure that the following initial conditions exist on the board:

- **a)** Audio input select switch in INT position.
- **b)** Mode switch in SSB position.
- **c)** Output amplifier's gain pot in fully clockwise position.
- **d)** Speaker switch in OFF position.

2. Turn on power to the **ST2201** board.

3. Turn the audio oscillator block's amplitude pot to its fully clockwise (MAX) position, and examine the block's output (TP14) on an oscilloscope.

This is the audio frequency sine wave which will be used as out modulating signal. Note that the sine wave's frequency can be adjusted from about 300Hz to approximately 3.4 KHz, by adjusting the audio oscillator's frequency pot.

Note : *That the amplitude of this audio modulating signal can be reduced to zero, by turning the audio oscillator's pot to its fully counter-clockwise (MIN) position.*

Leave the amplitude pot on its full clockwise position, and adjust the frequency pot for an audio frequency of 2 KHz, approx. (mid-way).

4. To achieve signal- sideband amplitude modulation, we will utilize the following three blocks on the **ST2201** module.

- **a)** Balanced modulator.
- **b)** Ceramic band pass filter
- **c)** Balanced modulator & band pass filter circuit 2.

We will now examine the operation of each of these blocks in detail.

5. Monitor the two inputs to the balanced modulator block, at TP15 and TP6 noting that:

- **a)** The signal TP15 is the audio frequency sinewave from the audio oscillator block. This is the modulating input to the balanced modulator block.
- **b)** The signal at TP6 is a sinewave whose frequency is slightly less than 455 KHz. It is generated by the 455 KHz oscillator block, and is the carrier input to the balanced modulator block.

6. Next, examine the output of the balanced modulator block (at TP17), together with the modulating signal at TP15 trigger the oscilloscope on the modulating signal. Check that the waveforms are as shown Figure 2.

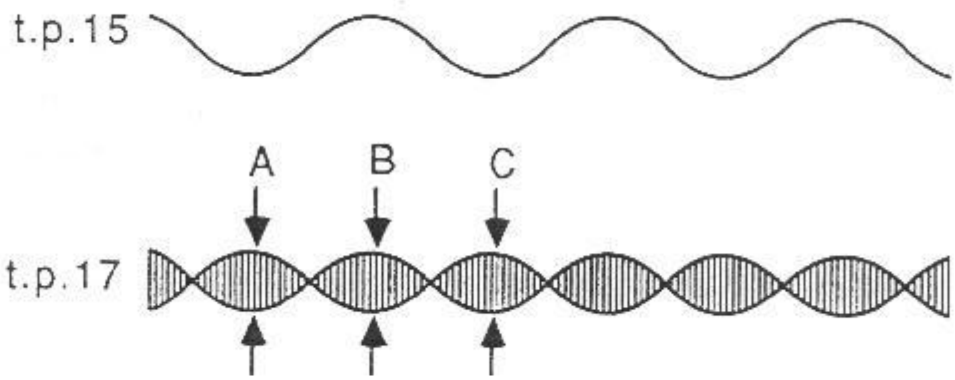


Figure 2

Note that it may be necessary to adjust the balanced modulator block's balance pot, in order to ensure that the peaks of TP17's waveform envelope (labeled A, B, C etc. in the above diagram) all have equal amplitude.

You will recall that the waveform at TP17 was encountered in the previous experiment this is a double-sideband suppressed carrier (DSBSC) AM waveform, and it has been obtained by amplitude-modulating the carrier sinewave at TP6 of frequency fc with the audio-frequency modulating signal at TP15 of frequency fm, and then removing the carrier component from the resulting AM signal, by adjusting the balance pot.

7. The DSBSC output from the balanced modulator block is next passed on to the ceramic filter block, whose purpose is to pass the upper sideband, but block the lower sideband. We will now investigate how this is achieved.

First note that the ceramic band pass filter has a narrow pass band centered around 455 KHz.

It was mentioned earlier that the frequency of the carrier input to the balanced modulator block has been arranged to be slightly less than 455 KHz. In fact, the carrier chosen so that, whatever the modulating frequency fm, the upper sideband (at fc+fm) will fall inside the filter's pass band, while the lower sideband (at fc-fm) always falls outside.

Consequently, the upper sideband will suffer little attenuation, while the lower sideband will be heavily attenuated to such an extent that it can be ignored. This shown in the frequency spectrum in Figure 3.

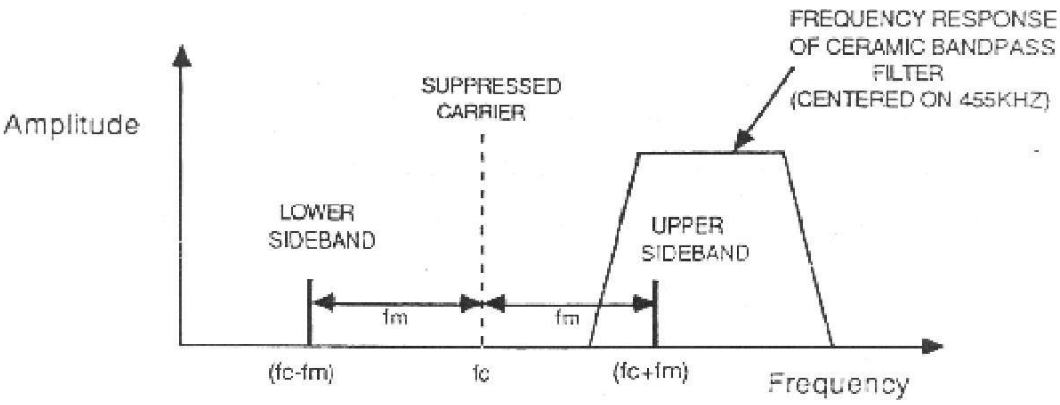


Figure 3.

8. Monitor the output of the ceramic band pass filter block (at TP20) together with the audio modulating signal (at TP15) using the later signal to trigger the oscilloscope. Note that the envelope of the signal at TP20 now has fairly constant amplitude, as shown in Figure 4.

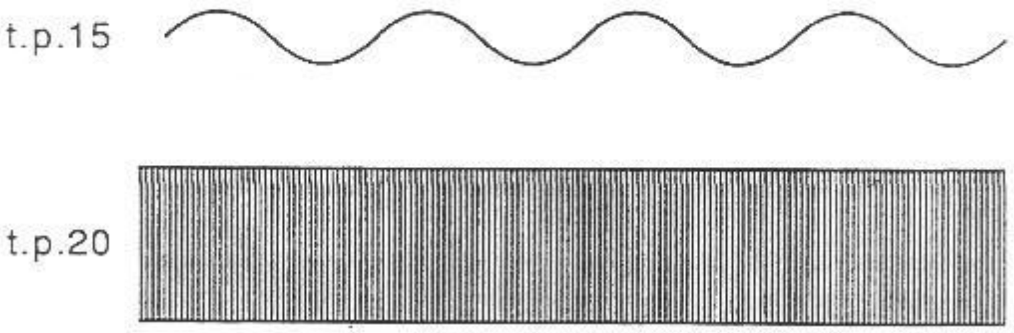


Figure 4.

If the amplitude of the signal at TP20 is not reasonably constant, adjust the balance pot in the balance modulator block to minimize variations in the signal's amplitude.

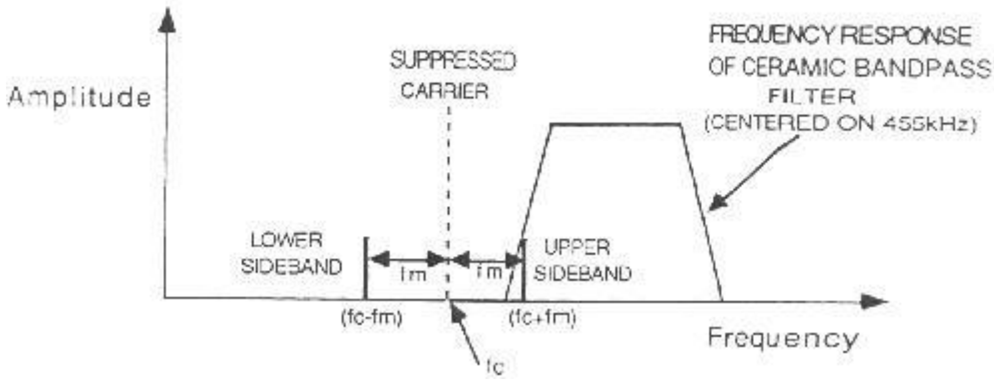
If the constant-amplitude waveform still cannot be obtained, then the frequency of the 455 KHz oscillator needs to be trimmed. To do this, follow the procedure given in chapter adjustment of the transmitter's tuned circuits.

9. Now, trigger the oscilloscope with the ceramic band pass filter's output signal (TP20) and note that the signal is a good, clean sinewave, indicating that the filter has passed the upper sideband only.

Next, turn the audio oscillator block's frequency pot throughout its range. Note that for most audio frequencies, the waveform is a good, clean sinewave, indicating that the lower sideband has been totally rejected by the filter. For low audio frequencies, you may notice that the monitored signal is not such a pure sinusoid. This is because the upper and lower sidebands are now very close to each other, and the filter can no longer completely remove the lower sidebands are now very close to each other, and the filter can no longer completely remove lower sideband.

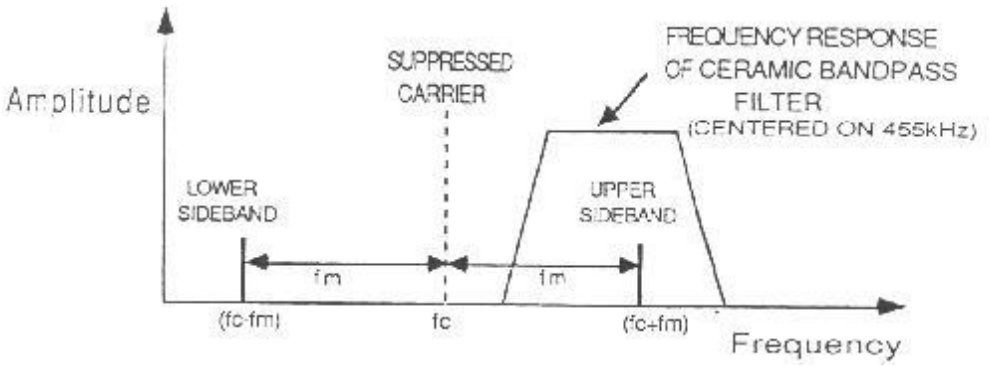
Nevertheless, the lower sideband's amplitude is sufficiently small compared with the upper sideband, that its presence can be ignored. Since the upper sideband dominates for all audio modulating frequencies, we say that single sideband (SSB) amplitude modulation has taken place.

10. Note that there is some variation in the amplitude of the signal at the filter's output (TP20) as the modulating frequency changes. This variation is due to the frequency response of the ceramic band pass filter, and is best explained by considering the spectrum of the filter's input signal at the MIN and MAX positions of the frequency pot, as shown in Figure 5.



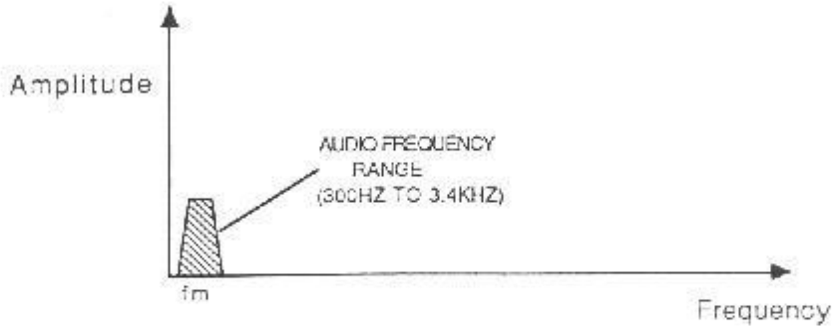
Modulating frequency fm = 300Hz (pot in MIN position)

Figure 5.

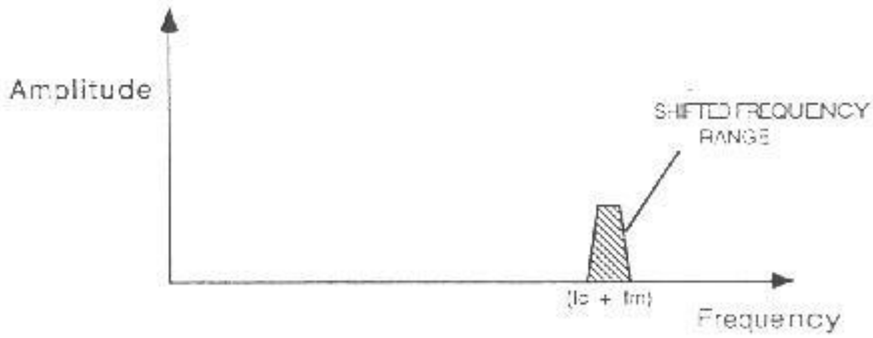


Modulating frequency fm = 3.4 KHz (pot in MAX position)
Figure 6.

11. Note that, by passing only the upper side band of frequency (fc+fm), all we have actually done is to shift out audio modulating signal of frequency fm up in frequency by an amount equal to the carrier frequency fc. This is shown in Figure 7.



Range of frequencies available from audio oscillator
Figure 7.



Corresponding range of output frequencies from ceramic band pass filter block

Figure 8.

12. With the audio oscillator block's frequency pot roughly in its midway position (arrowhead pointing towards the top), turn the block's amplitude pot to its MIN position, and note that the amplitude of the signal at the ceramic band pass filter's output (TP20) drops to zero.

This highlights one on the main advantages of SSB amplitude modulation if there is no modulating signal, then the amplitude of the SSB waveform drops to zero, so that no power is wasted.

Return the amplitude pot to its MAX position.

13. You will recall that we have used a ceramic band pass filter to pass the wanted upper sideband, but reject the unwanted lower sideband which was also produced by the amplitude modulation process. We used this type of filter because it passes the upper sideband, yet has a sufficiently sharp response to strongly attenuate the lower sideband, which is close by.

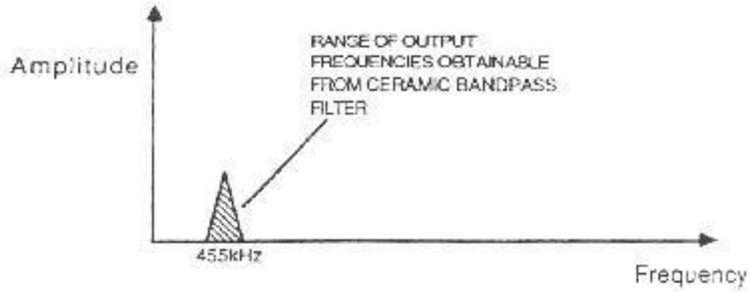
However, there is a disadvantage of this type of filter is the range of frequencies that the filter will pass is fixed during the filter's manufacture, and cannot subsequently be altered. The particular filter we are using has a pass band centered on 455 KHz, and this is why we have arranged for the wanted upper sideband to also be at about 455 KHz.

As we will see in later experiments, the **ST2201/ST2202** receiver will accept radiofrequency signals in the AM broadcast band, i.e. signals which fall in the frequency range of 525 KHz. However, since the SSB output from the ceramic band pass filter occupies a narrow band of frequencies around 455 KHz, it is not suitable for direct transmission to the receiver.

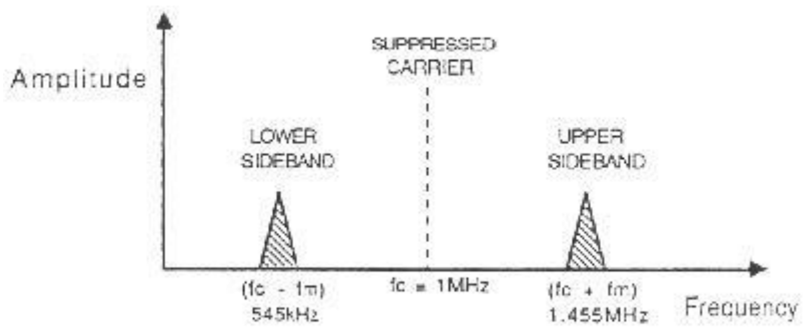
To overcome the problem, this narrow band of frequencies must be shifted up so that it falls within the AM broad cast band. This frequency-shifting operation is performed by the balanced modulator & band pass filter circuit 2, block, which contains a balanced modulator followed by a tuned circuit.

The operation is performed in two stages :

1. By amplitude-modulating at 1MHz carrier sinewave with the output from the ceramic band pass filter, and 'balancing out' the carrier component. This is shown in Figure 9.



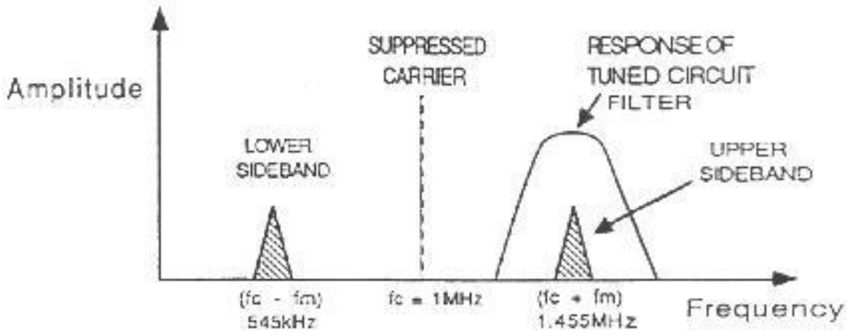
Spectrum of output from ceramic band pass filter block.
Figure 9.



Spectrum obtained by modulating 1MHz carrier with output from ceramic band pass filter

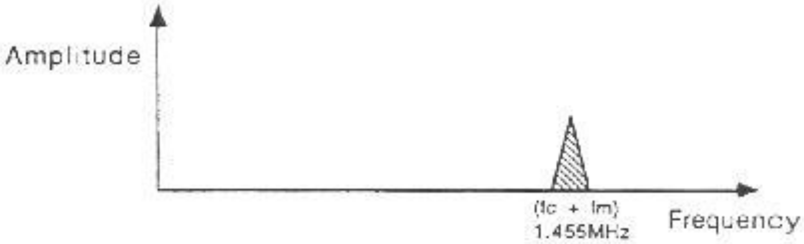
Figure 10.

2. By passing the Upper Side, and blocking the Lower Sideband, using a tuned circuit band pass filter, as shown in Figure 11.



Rejection of lower side band with tuned circuit band pass filter.

Figure 11.



Final SSB output from balanced modulator and band pass filter circuit 2.
Figure 12

Note that since there is a large gap between the upper and lower sidebands (a gap of about 910 KHz), a band pass filter with a very sharp response is not needed to reject the lower sideband, a simple tuned circuit band pass filter is quite sufficient.

14. Now examine the output of the balanced modulator & band pass filter circuit 2 block (TP22), and check that the waveform is a good sinewave of frequency approximately 1.45MHz.

This indicates that only the upper sideband is being passed by the block. Check that the waveform is reasonably good sinusoid for all audio modulating frequencies (i.e. all positions of the audio oscillator's frequency pot). If this is not the case, it may be that the balance pot (in the balanced modulator & band pass filter circuit 2 blocks) needs adjusting, to remove any residual carrier component at 1 MHz. If a reasonably clean sinewave still cannot be obtained for all audio frequencies, then the response of the tuned circuit band pass filter needs adjusting. This is achieved by adjusting transformer T4 in the balanced modulator & bandpass filter circuit 2 block. To do this, follow the procedure given in chapter adjustment of the transmitter's tuned circuits. Once the signal at TP22 is a reasonably good sinewave for all audio frequencies, we have achieved our objective of 'shifting up' the narrow range of output frequencies from the ceramic band pass filter block) which were around 455 KHz), so that they are now around 1.455 MHz. As a result, they now fall within the AM broadcast range of 525 KHz to 1.60MHz, and will be detectable by the **ST2202** receiver. When the modulating audio signal is swept over its entire range (a range of 3.4 KHz – 300Hz = 3.1 KHz), the SSB waveform at TP22 sweeps over the same frequency range. So single-sideband modulation has simply served to shift our range of audio frequencies up so they are centered around 1.455MHz.

15. Monitor the 1.455 MHz SSB signal (at TP22) together with the audio modulating signal (TP15), triggering the scope with the later. Reduce the amplitude of the audio modulating signal to zero (by means of the audio oscillator block's amplitude pot), and note that the amplitude of the SSB signal also drops to zero, as expected. Return the amplitude pot to its MAX position.

16. Examine the final SSB output (at TP22) together with the output from the output amplifier block (TP13). Note that the final SSB waveform appears, amplified slightly, at TP13. As we still see later, it is the output signal which will be transmitted to the receiver.

B. Setup for Single Sideband AM Reception

Procedure:

1. Position the **ST2201** & **ST2202** modules, with the **ST2201** board the left, and a gap of about three inches between them.

2. Ensure that the following initial conditions exist on the **ST2201** board.

- **a.** Audio oscillator's amplitude pot in full clockwise position.
- **b.** Audio input select switch in INT position.
- **c.** Mode switch in SSB position.
- **d.** Output amplifier's gain pot in full clockwise position.
- **e.** TX output select switch in ANT position.
- **f.** Audio amplifier's volume pot in full counter-clockwise position.
- **g.** Speaker switch in ON position.
- **h.** On board antenna in vertical position, and fully extended.

3. Ensure that the following initial conditions exist on the **ST2202** board.

- **a.** RX input select switch in ANT position.
- **b.** R.F amplifier's tuned circuit select switch in INT position.

c. R.F amplifier's gain pot in full clockwise position.

d. AGC switch in out position.

e. Detector switch in product position.

f. Audio amplifier's volume pot in fully counter clockwise position.

g. Speaker switch in 'ON' position.

h. Beat frequency oscillator switch in 'ON' position.

i. On - board antenna in vertical position, and fully extended.

4. Turn on power to the modules.

On the **ST2201** module, examine the transmitter's output signal (TP13), and make sure that this is a good SSB waveform, by checking that the signal is a reasonably good sinewave. If the monitored waveform is not a good sinewave at higher modulating frequencies i.e. when the frequency pot is approximately in centre, try adjusting the balance pots in the following two blocks, in order to ensure that the 455 KHz and 1 MHz carrier components have been completely balanced out.

a) Balanced modulator block, and

b) Balanced modulator & band pass circuit 2 block.

If the waveform at TP13 is still not good sinewave at higher modulating frequencies, then if it is likely that the frequency of **ST220**'s 455 KHz oscillator block needs adjusting. To do this, follow the procedure given in chapter adjustment of the transmitter's tuned circuits.

6. Turn **ST2201**'s amplitude pot (in the audio oscillator block) to its full counter clockwise (minimum amplitude) position and note that amplitude of the monitored output signal from **ST2201** (at TP13) drops to zero. This illustrates that the SSB waveform contains no carrier - if the amplitude of the modulating audio signal drops to zero, so does the amplitude of the transmitted SSB signal.

In **ST2201**'s audio oscillator block, return the amplitude pot to its fully clockwise (MAX) position, and put the frequency pot in its midway position.

7. We will now transmit the SSB waveform to the **ST2202** receiver.

Since **ST2201**'s TX output select switch is in the ANT position, the SSB signal at TP13 is fed to the transmitter's antenna. Prove this by touching **ST2201**'s antenna, and noting that the loading caused by your hand reduces the amplitude of the SSB waveform at TP13. The antenna will propagate this SSB waveform over a maximum distance of about 1.4 ft. We will now attempt to receive the propagated SSB waveform with the **ST2202** board, by using the receiver's on board antenna.

8. On the **ST2202** module, monitor the output of the IF amplifier 2 block (TP28) and turn the tuning dial until the amplitude of the monitored signal is at its greatest. Check that you have tuned into the SSB signal, by turning **ST2201**'s amplitude pot (in the audio oscillator block) to its MIN position, and checking that the monitored signal amplitude drops to zero. (This should occur at about 85-95) Return the amplitude pot to its MAX position.

9. Since the incoming SSB signal contains no carrier component, the receiver's AGC circuit cannot make use of incoming carrier amplitude, in order to control the receiver's gain. This means that the receiver's AGC circuit cannot be used for SSB reception, and must be switched off.

Consequently, it is very important to avoid overloading the receiver by transmitting an SSB signal which is too large for the receiver to handle. To ensure that overloading does not occur.

a. Turn the gain pot, in **ST2201**'s output amplifier block, so that the pots arrowhead is horizontal, and pointing to the left. This ensures that the amplitude of the transmitted SSB signal is small.

b. On the **ST2202** module, fine tune the tuning dial until the amplitude of monitored signal (at TP28) is at its greatest.

c. Adjust the gain pot, in **ST2202**'s RF amplifier block, until the amplitude of the monitored signal is about 2 volts pk/pk.

d. Repeat steps (2) and (3).

There should now be no risk of the **ST2202** receiver overloading.

10. For SSB reception, the following blocks of the receiver operate in the same way as they did for the reception of double-sideband AM signals.

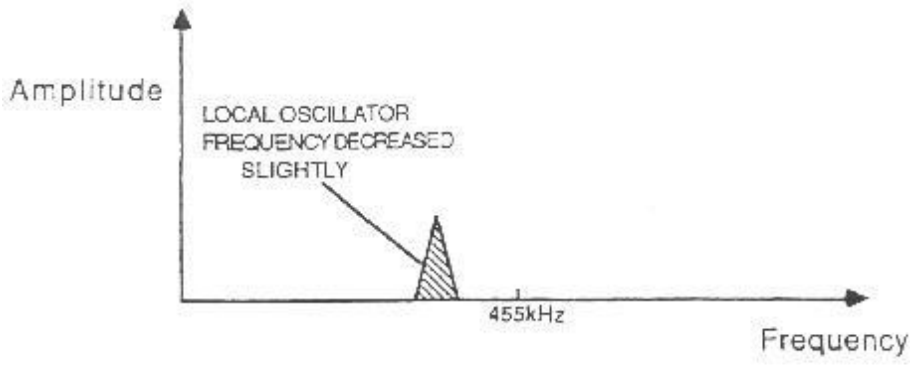
- R.F. Amplifier
- Local Oscillator
- Mixer
- I.F. Amplifier 1
- I.F. Amplifier 2

Since we have already discussed the operation of these blocks, we will only concern ourselves with how we demodulate the SSB signal from IF amplifier 2.

11. The receiver's beat frequency oscillator (BFO) produces a sinewave at the IF frequency of 455 KHz. This 455 KHz sine wave is input to the receiver's product detector block, where it is mixed with the SSB from I.F. amplifier.

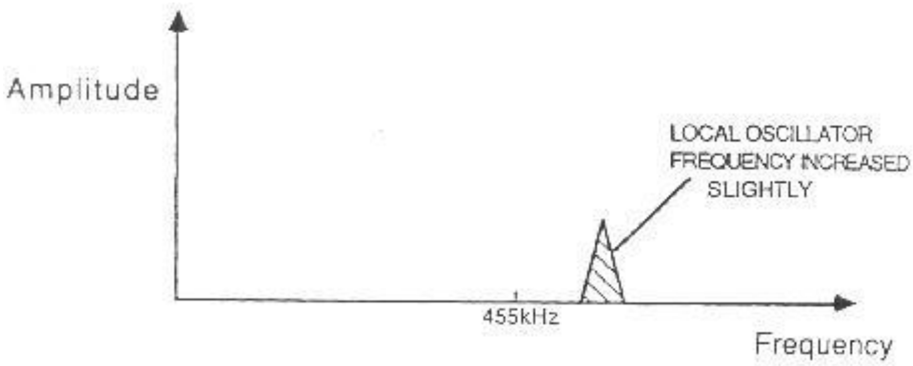
The actual frequency of the output signal from I.F. amplifier 2 will lie within a limited range of frequencies, which lie in the region of 455 KHz. The output signal can be varied over this limited range of frequencies, by adjusting the frequency of the transmitter's modulating signal from center (slightly lower and slightly higher).

In addition, the position of the limited range of frequencies from IF amplifier 2 will depend on the exact frequency of the receiver local oscillator output. If the oscillator's frequency is varied slightly from its present frequency, this range of frequencies can be moved both above, and below, 455 KHz. This is illustrated in Figure 16.



Frequency range of IF amplifier 2's output with slightly reduced local oscillator frequency

Figure 13.



Frequency range of IF amplifier 2's output with slightly increased local oscillator frequency.

Figure 14.

The product detector block mixes the output from the BFO with the output from I.F. amplifier block mixing process results in the generation of two new frequency components.

- a component whose frequency is the sum of the two input frequencies:
- a component whose frequency is the difference between the two input frequencies.

A low-pass filter at the output of the product detector rejects all frequencies except the difference frequency. Consequently, any slight difference in frequency between the BFO's output and I.F. amplifier 2's output will result in and audio frequency at the product detector's output. This audio frequency is then converted into sound by the receiver's audio amplifier block.

To demodulate out incoming SSB signal, we tune the Receiver's local oscillator so that the output frequency range form IF amplifier 2 is slightly below the 455

KHz. BFO frequency (as shown in part (a) of the last diagram), such that the difference frequency generated by the product detector is the same as the original transmitter audio modulating frequency. Then, as the frequency of the transmitter's modulating signal changes, the output from the product detector should follow it.

12. Monitor the output of **ST2202**'s beat frequency oscillator block (TP50), and note that this carries a sinewave of 455 KHz.

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13. On the **ST2202** module, monitor the output of the product detector block (at TP37), together with the output of the audio amplifier block (TP39), triggering the scope with the later signal.

Note : *There will be no signal at TP39 if the audio amplifier's volume pot is in its fully counter-clockwise (minimum) position. Vary the frequency of the Transmitter's audio modulating signal by adjusting the audio oscillator's frequency pot on the* **ST2201** *module.*

Note : *There will be no signal at TP39 if the audio amplifier's volume pot is in fully counter-clockwise (minimum) position.*

Also, try briefly reducing the amplitude of the Transmitter's modulating signal to zero (by turning the audio oscillator's amplitude pot fully clockwise), and note that the receiver's output amplitude also drops to zero.

14.

Result: The audio modulating signal is demodulated back from the SSB signal.

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Frequently Asked Questions

Que 1.What is SSB?

Ans.Single-sideband modulation (SSB) is a refinement of amplitude modulation that more efficiently uses electrical power and bandwidth. It is closely related to vestigial sideband modulation (VSB).

Que 2.What is Hilbert Transform?

Ans.Hilbert Transform is an ideal Phase Shifter which shifts different frequency components present in the signal by pi/2.

Que 3.What are the advantages of SSB ?

Ans Bandwidth Requirement of SSB is half as compared to DSB System.

SSB is a Power efficient scheme in which only 33% power is being utilized.

Que 4.What are the applications of SSB ?

Ans.SSB System is used in telemetry, land and air mobile communication , military communication, navigation and amateur radio. Most of these applications are point to point communication systems.