Departme
Electronics and Instrumentation Engine

COMMUNICATION SYSTEMS

Course Code :17EI05

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SSBSC Modulation

In the previous chapters, we have discussed DSBSC modulation and demodulation. The DSB
modulated signal has two sidebands. Since, the two sidebands carry the same information, there is
need to transmit both sidebands. We can eliminate one sideband.

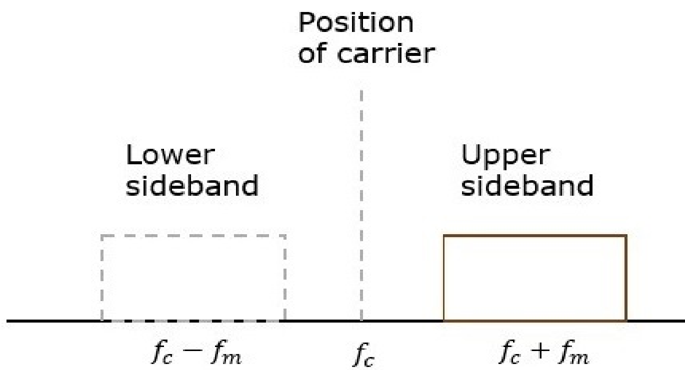
As both DSB_SC and standard AM waste a lot of power and occupy large bandwidth($2f_m$).

The process of suppressing one of the sidebands along with the carrier and transmitting a sing
sideband is called as **Single Sideband Suppressed Carrier** system or simply **SSBSC**. It is plotted as show
in the following figure.

- The suppressed carrier is further improved by sending only one sideband
- This not only uses less power but also only half of the bandwidth and it is called single sideba suppressed carrier (SSB_SC)

In the above figure, the carrier and the lower sideband are suppressed. Hence, the upper sideband is used for transmission. Similarly, we can suppress the carrier and the upper sideband while transmitting the lower sideband.

This SSBSC system, which transmits a single sideband has high power, as the power allotted for both the carrier and the other sideband is utilized in transmitting this Single Sideband.



Carrier and a sideband are suppressed and single sideband is allowed for transmission

SSBSC Modulation

Time domain representation or Mathematical Expressions

Let us consider the same mathematical expressions for the modulating and the carrier signals as we have considered in the earlier chapters.

i.e., Modulating signal $m(t)=A_m\cos(2\pi f_m t)$

Carrier signal $c(t)=A_c\cos(2\pi f_c t)$

Mathematically, we can represent the equation of SSBSC wave as

$$s(t)_{USB} = (A_m A_c / 2)\cos[2\pi(f_c+f_m)t]$$ for the upper sideband

or $$s(t)_{LSB}=(A_m A_c/2)\cos[2\pi(f_c-f_m)t]$$ for the lower sideband

$$s(t)_{USB} = (A_m A_c / 2)\cos[2\pi f_c t+2\pi f_m t]$$

cos(a + b) = cos(a)cos(b) – sin(a)sin

$$s(t)_{USB} = (A_m A_c / 2)[\cos(2\pi f_c t)\cos(2\pi f_m t)- \sin(2\pi f_c t)\sin(2\pi f_m t)]$$

$$s(t)_{USB} = (A_c / 2)[m(t)\cos(2\pi f_c t))- \hat{m}(t)\sin(2\pi f_c t))]$$

Where $\hat{m}(t) = A_m\sin(2\pi f_m t)$ which is the Hilbert transform of m(t). Hilbert transform of a signal obtained by givin -90^0 phase shift to each frequency component of a signal. It provide 90^0 phase shift to signal. Hilbert is used to provide phase shift but Fourier Transform to convert time domain to frequency domain.

SSBSC Modulation

Bandwidth of SSBSC Wave

We know that the DSBSC modulated wave contains two sidebands and its bandwidth is $2f_m$. Since SSBSC modulated wave contains only one sideband, its bandwidth is half of the bandwidth of DSB modulated wave.

i.e., ***Bandwidth of SSBSC modulated wave*** $=2f_m / 2=f_m$

Therefore, the bandwidth of SSBSC modulated wave is f_m and it is equal to the frequency of modulating signal.

SSBSC Modulation

Power Calculations of SSBSC Wave:

Consider the following equation of SSBSC modulated wave.

$$s(t) = (A_m A_c / 2)\cos[2\pi(f_c+f_m)t]$$ for the upper sideband

or

$$s(t)=(A_m A_c/2)\cos[2\pi(f_c-f_m)t]$$ for the lower sideband

Power of SSBSC wave is equal to the power of any one sideband frequency components.

$$P_t=P_{USB}=P_{LSB}$$

$$Power\ (P) = \frac{V_{rms}^2}{R} = \frac{(V_m/\sqrt{2})^2}{R}$$

$$P_{USB} = \frac{(A_m A_C / 2\sqrt{2})^2}{R} = \frac{(A_m)^2 (A_C)^2}{8R}$$

SSBSC Modulation

$$P_{USB} = P_{LSB} = \frac{A_m^2 A_c^2}{8R}$$

$$P_t = P_{USB} = P_{LSB} = \frac{A_m^2 A_c^2}{8R}$$

Applications

- For power saving requirements and low bandwidth requirements.
- In land, air, and maritime mobile communications.
- In point-to-point communications.
- In radio communications.
- In television, telemetry, and radar communications.
- In military communications, such as amateur radio, etc.

SSBSC Modulation

Advantages:

- Bandwidth or spectrum space occupied is lesser than AM and DSBSC waves.
- Transmission of more number of signals is allowed.
- Power is saved.
- High power signal can be transmitted.
- Less amount of noise is present.
- Signal fading is less likely to occur.

Disadvantages:

- The generation and detection of SSBSC wave is a complex process.
- The quality of the signal gets affected unless the SSB transmitter and receiver have an excellent frequency stability.

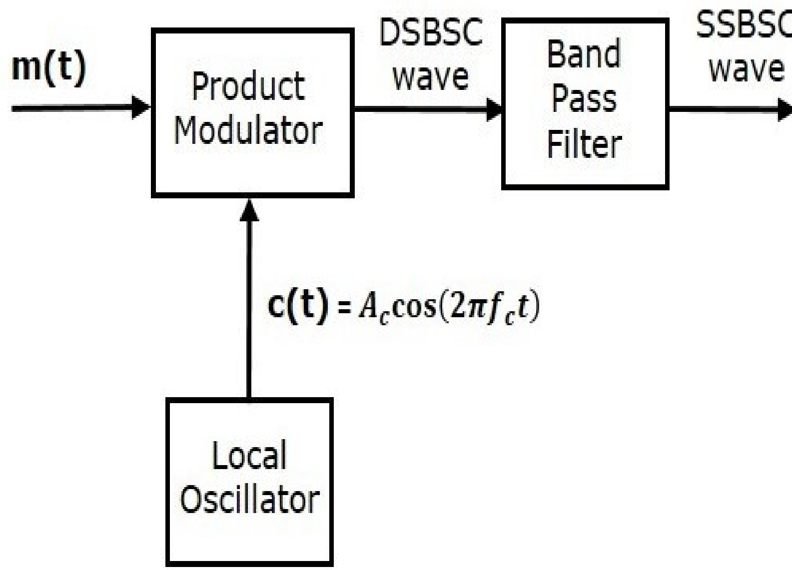
SSBSC Modulation

SSBSC modulators, which generate SSBSC wave. We can generate SSBSC wave using the followi
two methods.

- Frequency discrimination method
- Phase discrimination method

Frequency Discrimination Method:

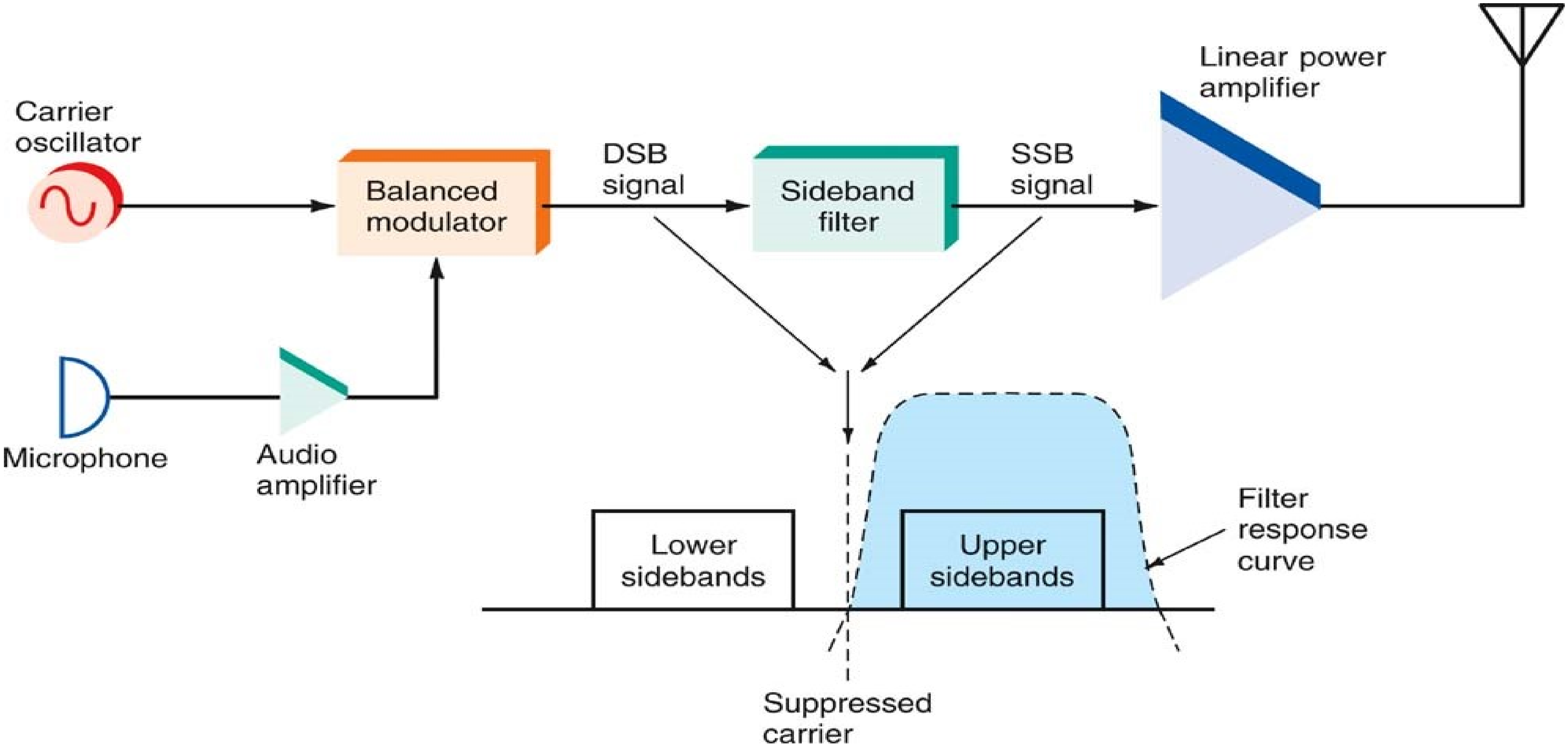
The following figure shows the block diagram of SSBSC modulator using frequency discrimination method.



In this method, first we will generate DSBSC wave with the help of the product modulator. Then, apply this DSBSC wave as an input of band pass filter. This band pass filter produces an output, which is SSBSC wave.

Select the frequency range of band pass filter as the spectrum of the desired SSBSC wave. This means the band pass filter can be tuned to either upper sideband or lower sideband frequencies to get the respective SSBSC wave having upper sideband or lower sideband.

Limitations of Frequency discrimination method are that as the base band signal must be appropriately related t
the carrier signal frequency, the designing of band pass filter is difficult if the carrier frequency is quite higher tha
the bandwidth of the baseband signal. The system is not useful for video communication purpose.



SSB transmitter using the filter method.

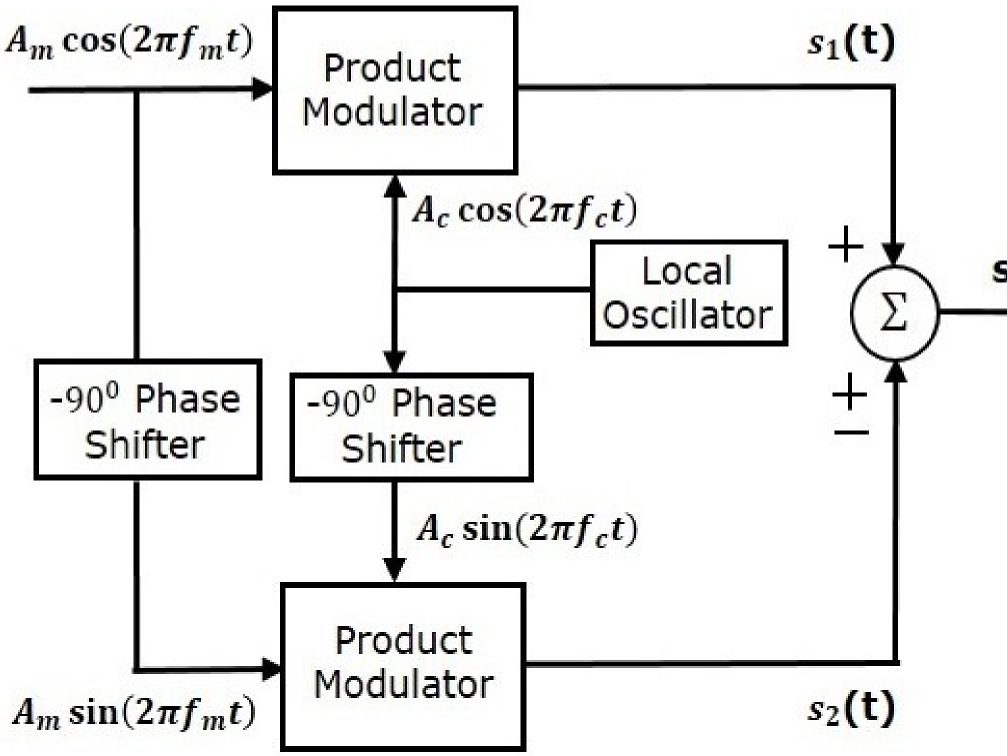
SSBSC Modulation

Phase Discrimination Method:

The following figure shows the block diagram of SSBSC modulator using phase discrimination metho

This block diagram consists of two product modulators, two -90^0 phase shifters, one local oscillator and one summer block. The product modulator produces an output, which is the product of two inputs. The -90^0phase shifter produces an output, which has a phase lag of -90^0 with respect to the input.

The local oscillator is used to generate the carrier signal. Summer block produces an output, which is either the sum of two inputs or the difference of two inputs based on the polarity of inputs.



SSBSC Modulation

The modulating signal $A_m\cos(2\pi f_m t)$ and the carrier signal $A_c\cos(2\pi f_c t)$ are directly applied as inputs to the upper product modulator. So, the upper product modulator produces an output, which is the product of these two inputs.

The output of upper product modulator is

$$s(t)=A_mA_c\cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$s_1(t)=\frac{A_mA_c}{2}\cos\,[2\pi(f_c+f_m\,)t]+\frac{A_mA_c}{2}\cos\,[2\pi(f_c-\,f_m\,)t]$$

The modulating signal $A_m\cos(2\pi f_m t)$ and the carrier signal $A_c\cos(2\pi f_c t)$ are phase shifted by -90^0 befo applying as inputs to the lower product modulator. So, the lower product modulator produces an outp which is the product of these two inputs.

The output of lower product modulator is

$$s_2(t)=A_mA_c\cos(2\pi f_m t-90^0)\cos(2\pi f_c t-90^0)$$

SSBSC Modulation

$$s_2(t)=A_m A_c \sin(2\pi f_m t)\sin(2\pi f_c t)$$

$$s_2(t) = -\frac{A_m A_c}{2}\cos\ [2\pi(f_c + f_m\ )t] + \frac{A_m A_c}{2}\cos\ [2\pi(f_c - f_m\ )t]$$

Add s1(t) and s2(t) in order to get the SSBSC modulated wave s(t) having a lower sideband.

$$s(t)=s_1(t) + s_2(t) = A_m A_c \cos[2\pi(f_c - f_m)t]$$

Subtract s2(t) from s1(t) in order to get the SSBSC modulated wave s(t) having a upper sideband.

$$s(t)=s_1(t) - s_2(t) = A_m A_c \cos[2\pi(f_c + f_m)t]$$

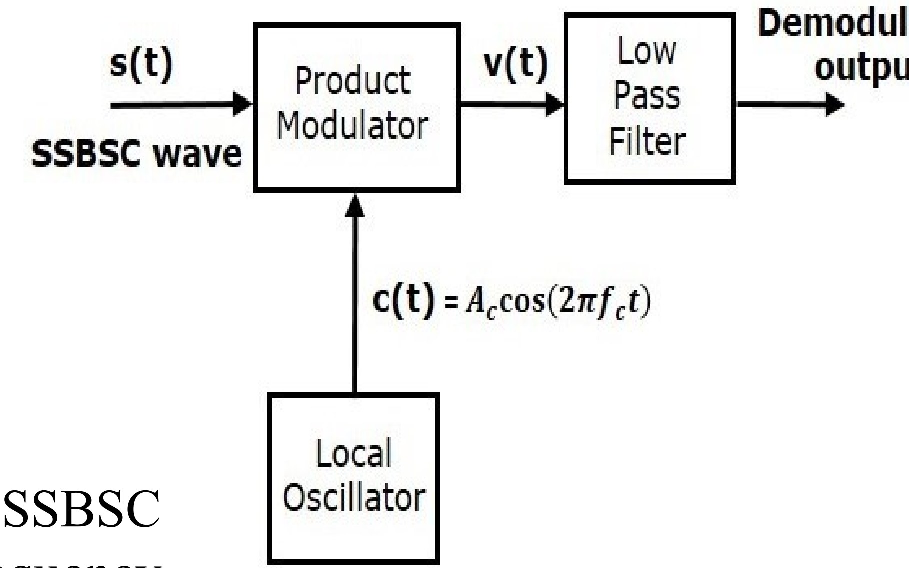
Hence, by properly choosing the polarities of inputs at summer block, we will get SSBSC wave having a upper sideband or a lower sideband.

SSBSC Demodulation

The process of extracting an original message signal from SSBSC wave is known as detection or demodulation of SSBSC. Coherent detector is used for demodulating SSBSC wave.

Coherent Detector:

Here, the same carrier signal (which is used for generating SSBSC wave) is used to detect the message signal. Hence, this process of detection is called as **coherent** or **synchronous detection**. Following is the block diagram of coherent detector.



In this process, the message signal can be extracted from SSBSC wave by multiplying it with a carrier, having the same frequency and the phase of the carrier used in SSBSC modulation. The resulting signal is then passed through a Low Pass Filter. The output of this filter is the desired message signal.

SSBSC Demodulation

Consider the following **SSBSC** wave having a **lower sideband**.

$$s(t) = \frac{A_m A_c}{2} \cos\ [2\pi(f_c - f_m)t]$$

The output of the local oscillator is

$$c(t)=A_c \cos(2\pi f_c t)$$

From the figure, we can write the output of product modulator as

$$v(t)=s(t)c(t)$$

Substitute s(t) and c(t)values in the above equation.

$$V(t) = \frac{A_m A_c}{2} \cos\ [2\pi(f_c - f_m)t] A_c \operatorname{Cos}(2\pi f_c t)$$

$$V(t) = \frac{A_m {A_c}^2}{4} \{\cos\ [2\pi(2f_c - f_m)t] + \operatorname{Cos}(2\pi f_m)t\}$$

SSBSC Demodulation

$$V(t) = \frac{A_m A_c{}^2}{4} \cos\left[2\pi(2f_c - f_m)t\right] + \frac{A_m A_c{}^2}{4} \mathrm{Cos}(2\pi f_m)t$$

In the above equation, the second term is the scaled version of the message signal. It can be extracted by passing the above signal through a low pass filter.

Therefore, the output of low pass filter is

$$V_0(t) = \frac{A_m A_c{}^2}{4} \mathrm{Cos}(2\pi f_m t)$$

Here, the scaling factor is $\frac{A_c{}^2}{4}$

We can use the same block diagram for demodulating SSBSC wave having an upper sideband. Consider th following **SSBSC** wave having an **upper sideband**.

$$s(t) = \frac{A_m A_c}{2} \cos\left[2\pi(f_c + f_m)t\right]$$

SSBSC Demodulation

$c(t)=A_c\cos(2\pi f_c t)$

We can write the output of the product modulator as $v(t)=s(t)c(t)$

$$V(t)=\frac{A_m A_c}{2}\cos\left[2\pi(f_c+f_m)t\right]A_c\,\mathrm{Cos}(2\pi f_c t)$$

$$V(t)=\frac{A_m A_c{}^2}{4}\cos\left[2\pi(2f_c+f_m)t\right]+\frac{A_m A_c{}^2}{4}\mathrm{Cos}(2\pi f_m)t$$

In the above equation, the second term is the scaled version of the message signal. It can be extrac by passing the above signal through a low pass filter.

Therefore, the output of low pass filter is $$V_0(t)=\frac{A_m A_c{}^2}{4}\mathrm{Cos}(2\pi f_m t)$$

Here, the scaling factor is $\frac{A_c{}^2}{4}$

Therefore, we get the same demodulated output in both the cases by using coherent detector.

SSB Applications:

- SSB is used in the systems which require minimum bandwidth such as telephone multiplex system and it is not used in broadcasting

- Point to point communications at frequency **below 30 MHz** – mobile communications, military, navigation radio etc where power saving is needed it -I

Dbtain the

otal power as well as power of sidebands(ii)Frequency domain

resentationfor the givenamplitude modulated (AM) signal

$=10 \cos 2\pi \times 10^6 t(1+ 3 \cos 2\pi \times 10^3 t)$. $\Leftrightarrow s(t) = A_c \cos \omega_c t (1+ u \cos \omega_m t)$.

$$s(t) = A_c(1+u\cos(\omega_m t))\cos(\omega_c t)$$

$$s(t) = A_c \cos(2\pi f_c t) + [uA_c \cos(2\pi f_m t)][\cos(2\pi f_c t)]$$

$$= A_c \cos(2\pi f_c t) + \frac{u A_c}{2}\cos[2\pi(f_c + f_m)t]$$

$$+ \frac{uA_c}{2}\cos[2\pi(f_c - f_m)t]$$

$$P_t = P_c + \frac{u^2}{4}P_c + \frac{u^2}{4}P_c$$

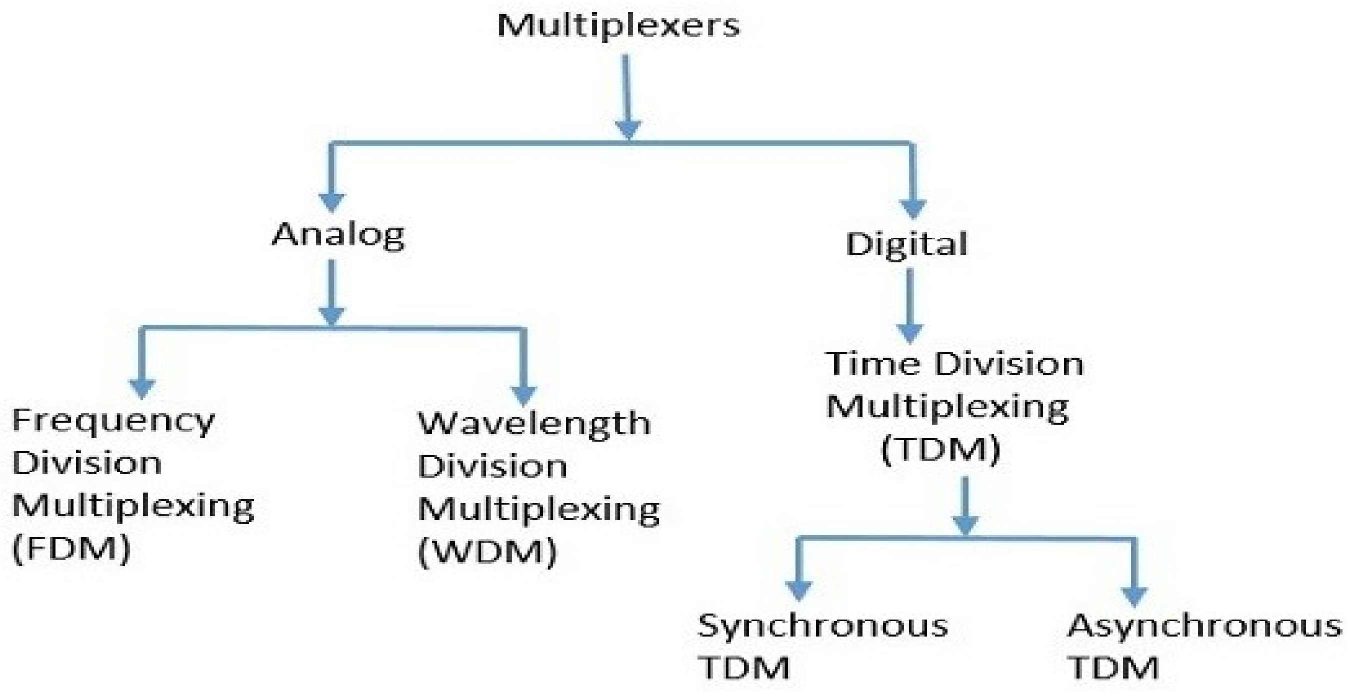
$$= P_c + \frac{u^2}{2}P_c = P_c[1 + \frac{u^2}{2}]$$

ly Fourier Transform to above equation

$$= \frac{A_C}{2}[\delta(f - f_c) + \delta(f + f_c)] + \frac{\mu A_C}{4}[\delta(f - f_c - f_m) + \delta(f + f_c + f_m)] + \frac{\mu A_C}{4}[\delta(f - f_c + f_m) + \delta(f + f_c$$

Multiplexing

Multiplexing is the process of combining multiple signals into one signal, over a shared medium. If the analog signals are multiplexed, then it is called as **analog multiplexing**. Similarly, if the digital signals are multiplexed, then it is called as **digital multiplexing**.



Frequency Division Multiplexing(FDM)

Frequency division multiplexing (FDM) is a technique of multiplexing which means combining more than one signal over a shared medium. In FDM, signals of different frequencies are combined for concurrent transmission.

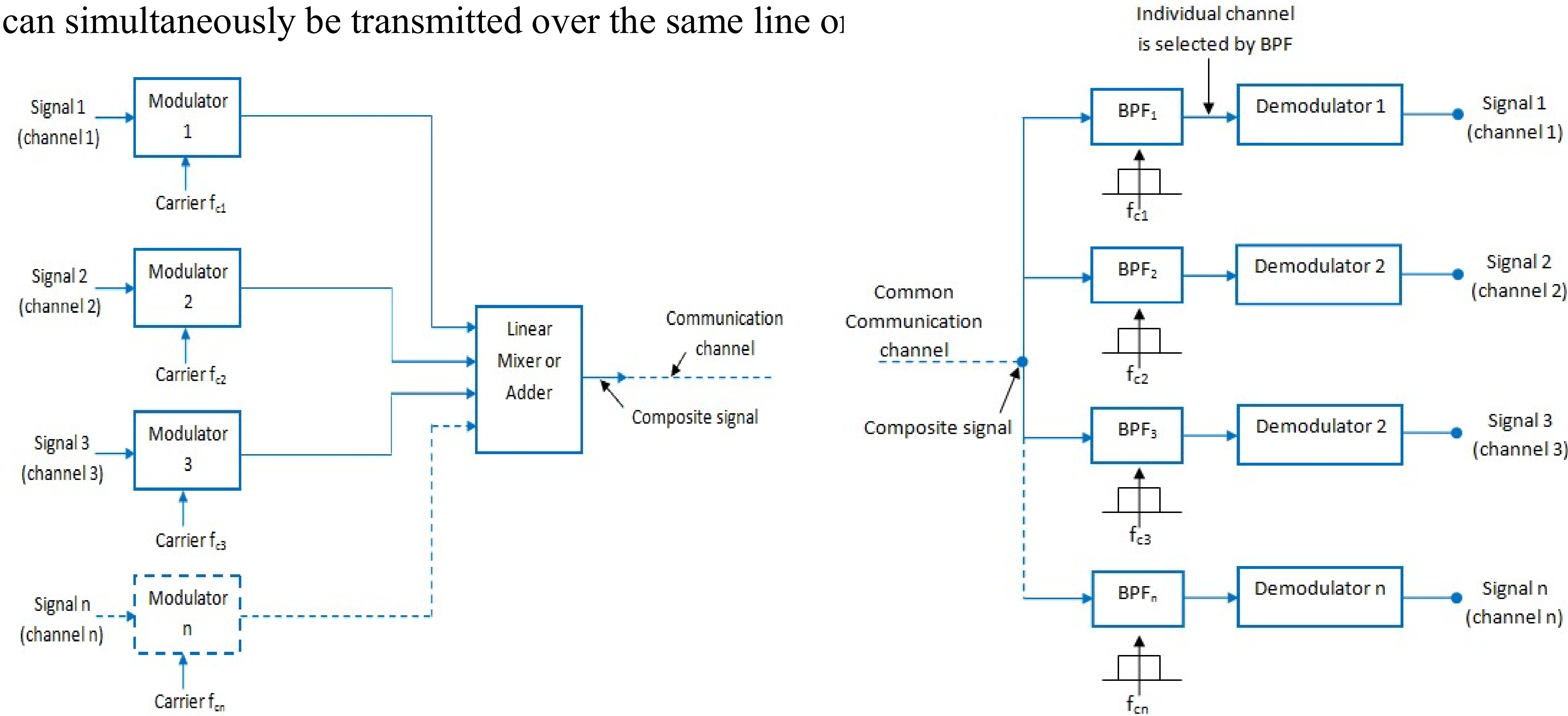
Concept and Process

In FDM, the total bandwidth is divided to a set of frequency bands that do not overlap. Each of these bands is a carrier of a different signal that is generated and modulated by one of the sending devices. The frequency bands are separated from one another by strips of unused frequencies called the guard bands, to prevent overlapping of signals.

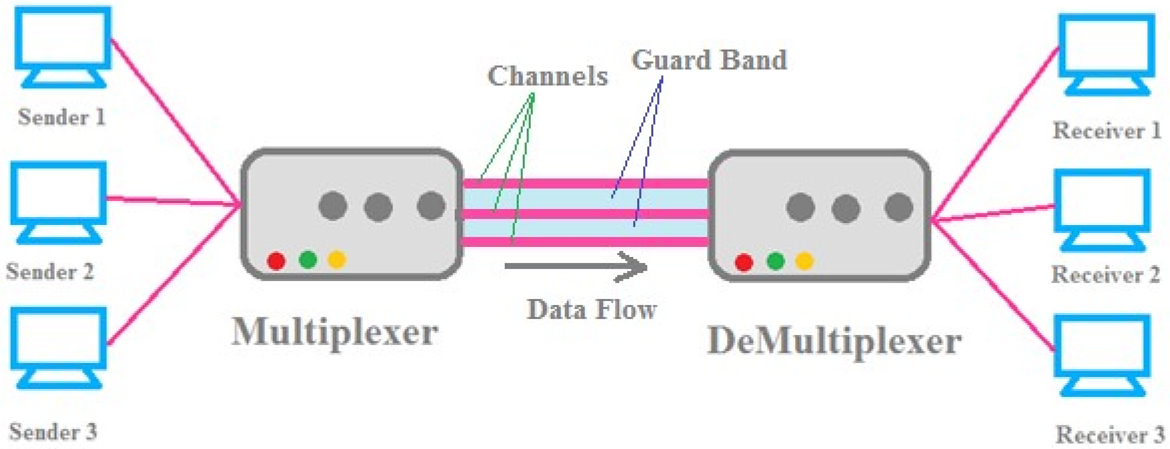
The modulated signals are combined together using a multiplexer (MUX) in the sending end. The combined signal is transmitted over the communication channel, thus allowing multiple independent data streams to be transmitted simultaneously. At the receiving end, the individual signals are extracted from the combined signal by the process of demultiplexing (DEMUX).

Frequency Division Multiplexing(FDM)

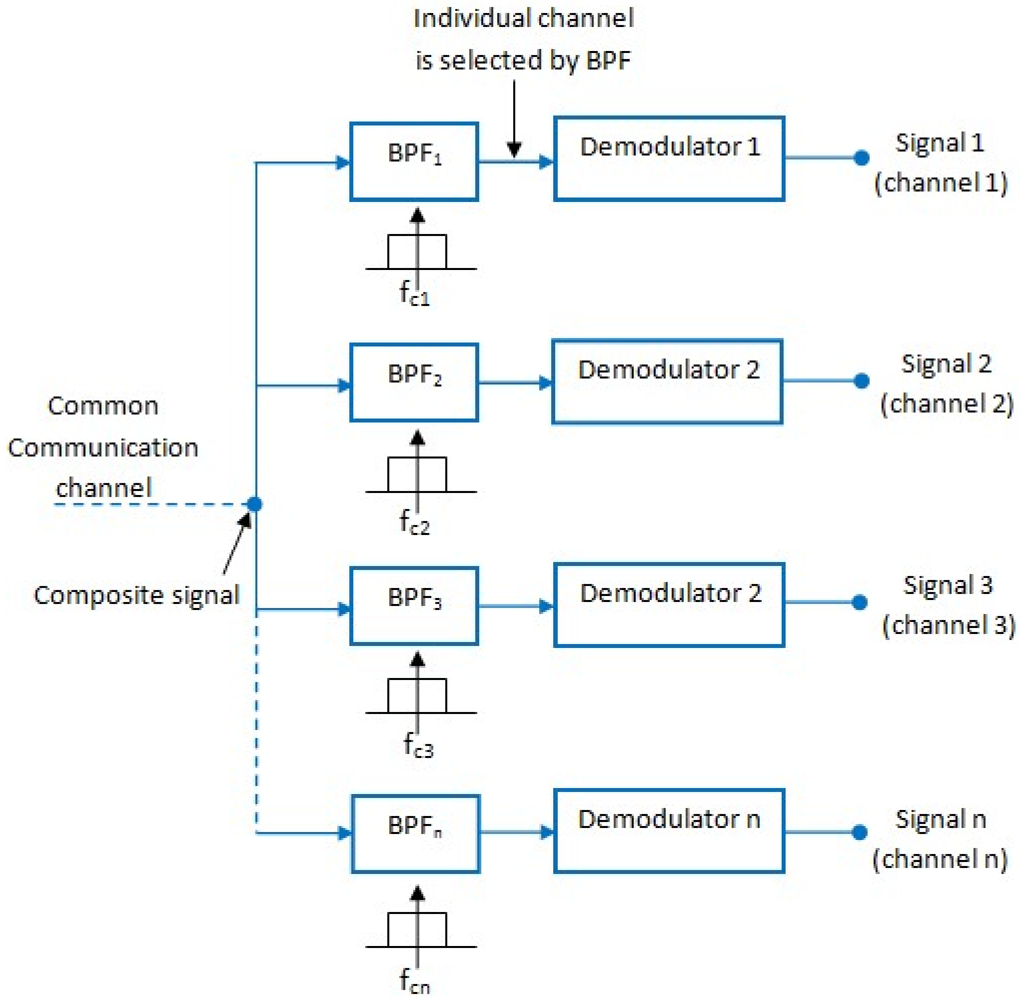
Frequency-Division Multiplexing (FDM) is a signal transmission technology in which multiple signals can simultaneously be transmitted over the same line o



SSBSC Modulation



Frequency Division Multiplexing



Individual channel
is selected by BPF
BPF1
Demodulator 1
Signal 1
(channel 1)
fc1
BPF2
Demodulator 2
Signal 2
(channel 2)
Common
Communication
channel
fc2
Composite signal
BPF3
Demodulator 2
Signal 3
(channel 3)
fc3
BPFn
Demodulator n
Signal n
(channel n)
fcn