CHAPTER 5

Amplitude Modulation

(Part 4 of 4)

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

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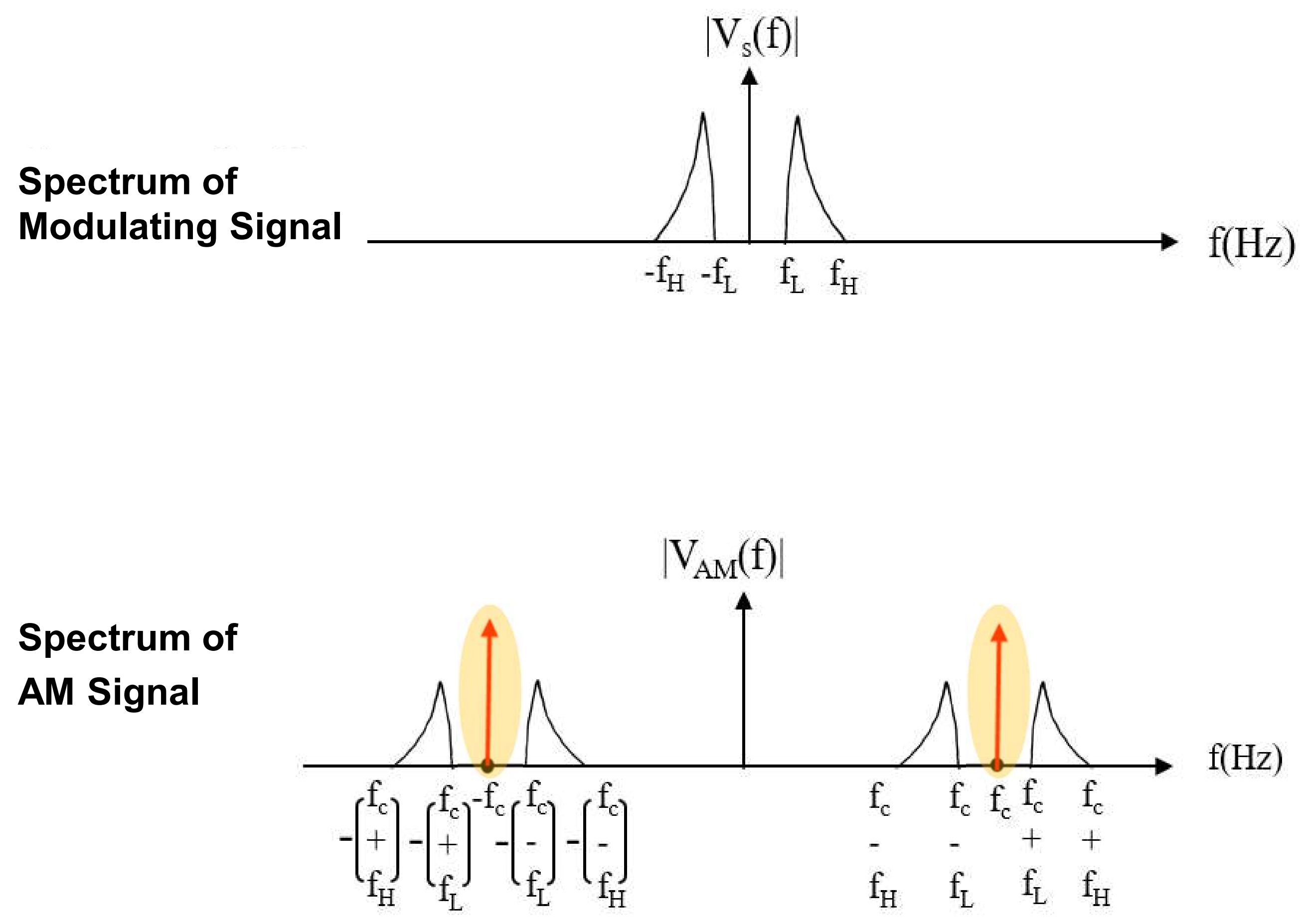
- **AM signal consists of a carrier component and two sidebands.**
- **A large portion of total transmitted power lies in the carrier component.**

e.g. Single-tone AM signal:

Carrier power > 67% of total power

Sideband power < 17% of total power

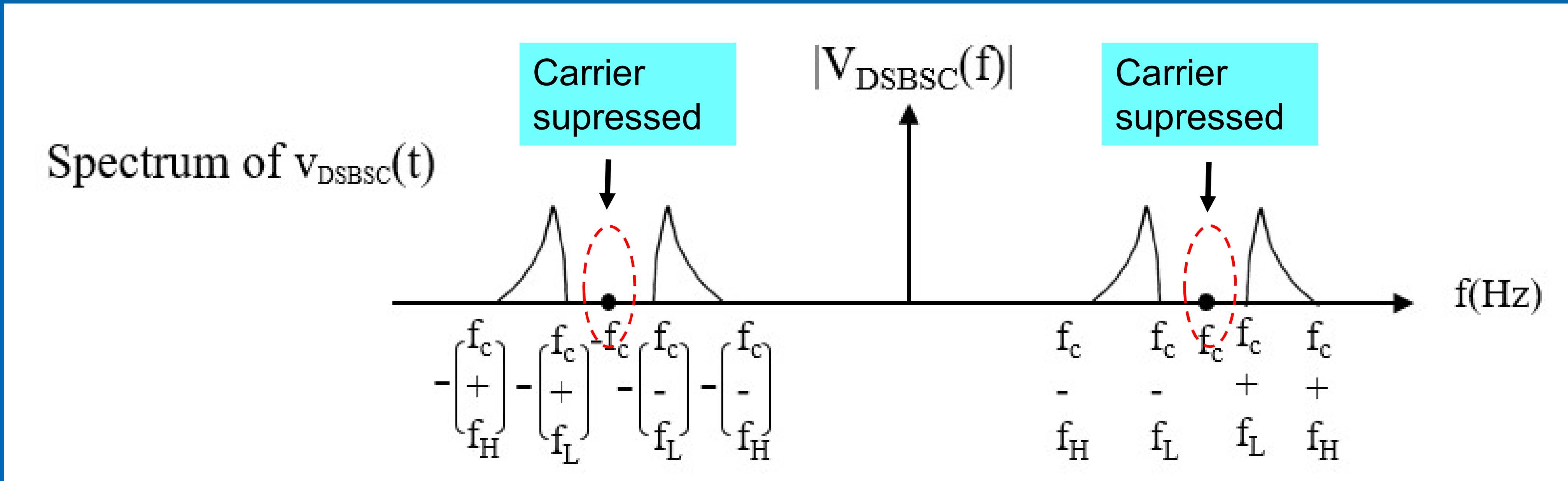
- **The carrier component power is a waste.**



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

- **The modified AM process that contains no carrier component but only two sidebands is known as Double SideBand Suppressed Carrier (DSBSC) modulation.**

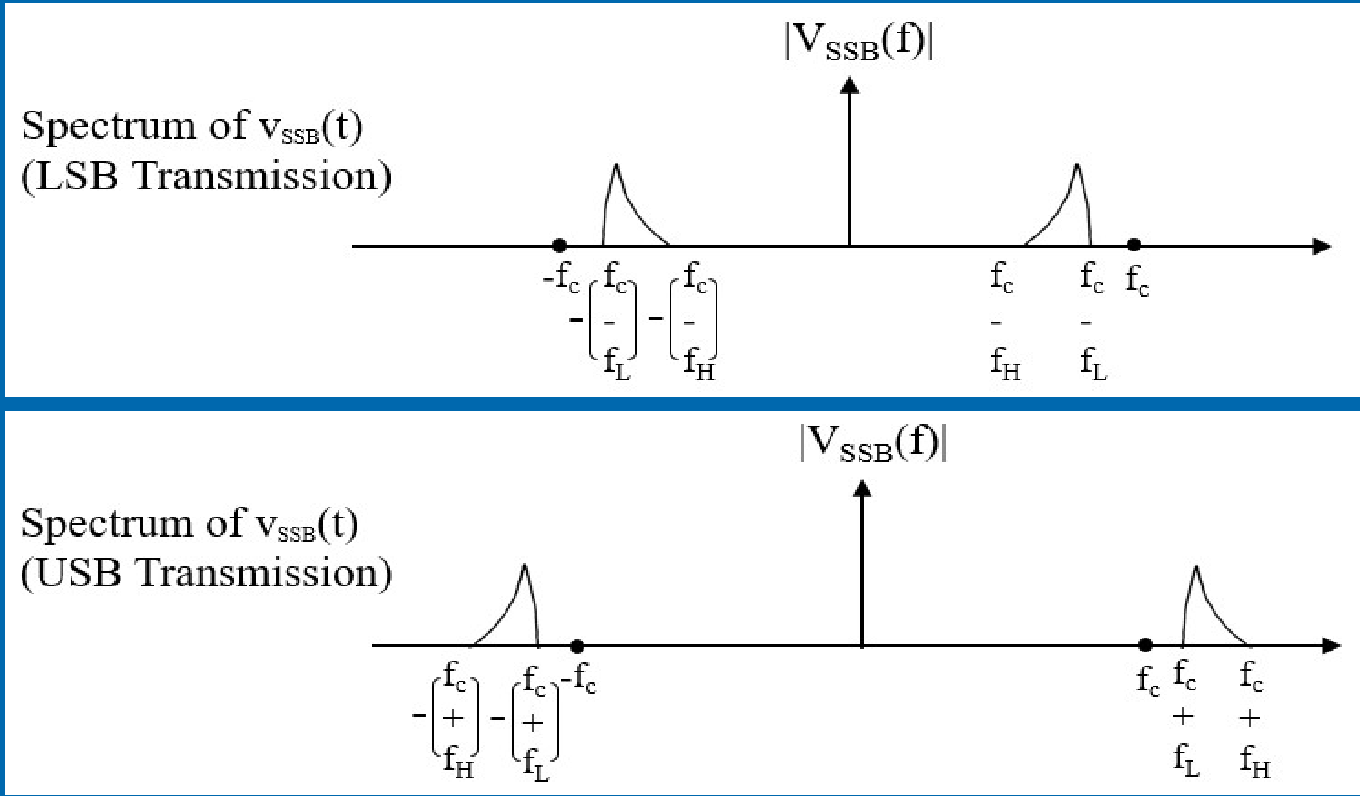
- **In DSBSC, the carrier is suppressed, leaving only the two sidebands to be transmitted.**



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

- **The information contained in the lower-sideband is identical to the information contained in the upper-sideband.**
- **The modified AM process that transmits one sideband only is known as Single Sideband (SSB) modulation.**

In SSB, either the USB or LSB can be transmitted.



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Time domain representation of DSBSC signal

recall

$v_{AM}(t) = V_c\cos 2\pi f_c t + v_s(t)\cos 2\pi f_c t$

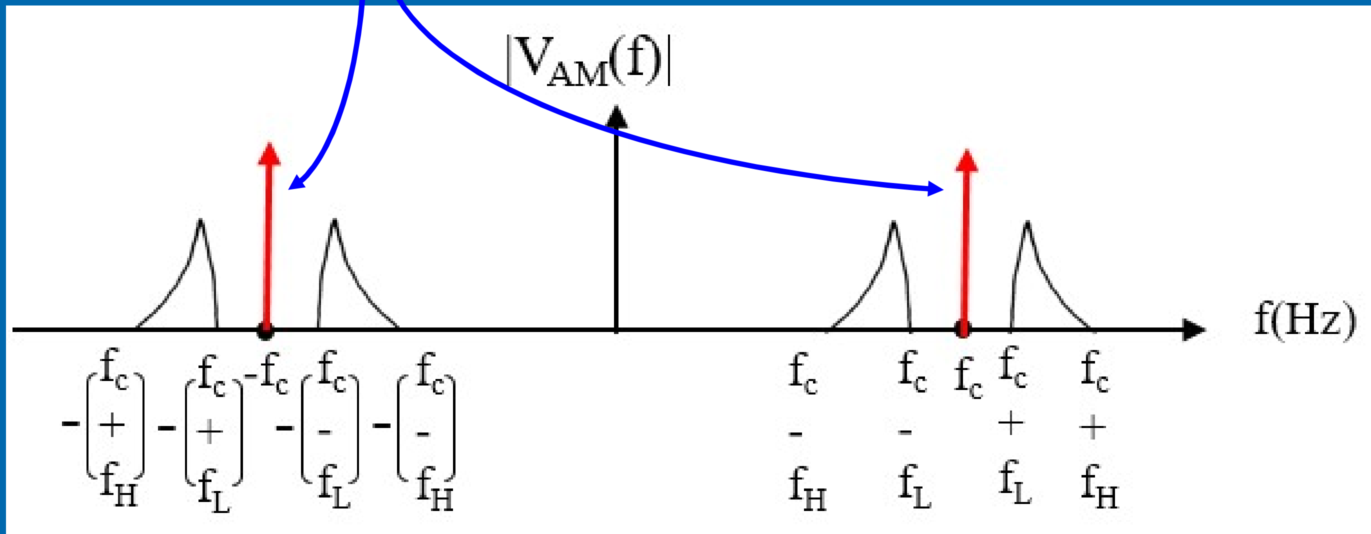
carrier component

Produces the USB and LSB

Remove carrier component

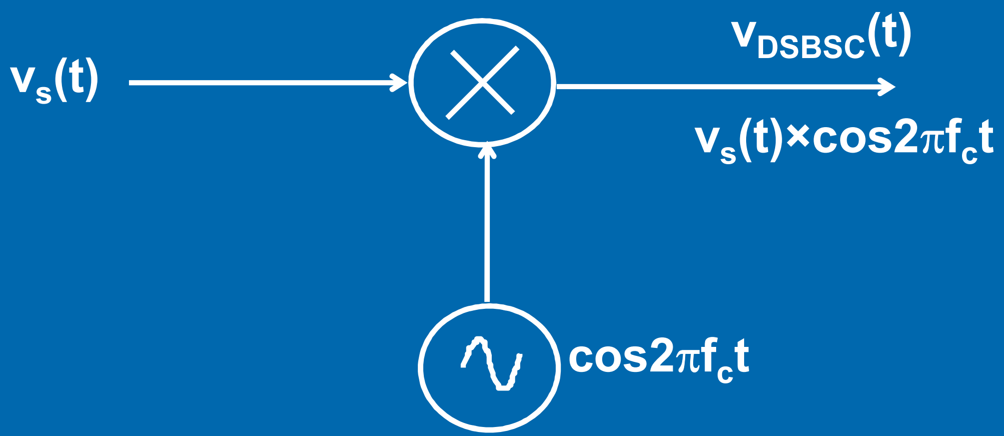
DSBSC signal

$v_{DSBSC}(t) = v_s(t)\cos 2\pi f_c t$



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

$$v_{DSBSC}(t) = v_s(t)\cos 2\pi f_c t$$

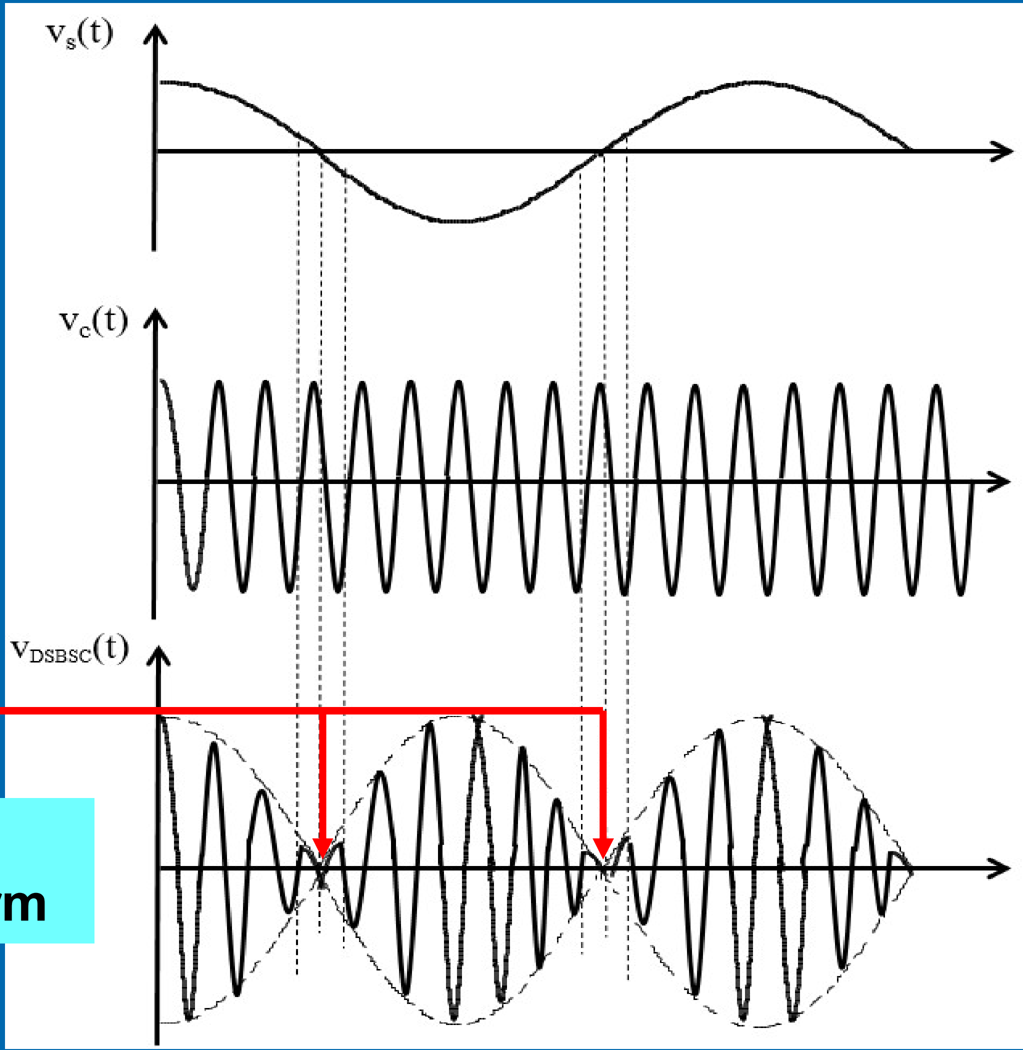


The DSBSC Modulator

Balanced Modulator

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

The DSBSC waveform for a sinusoidal modulating signal

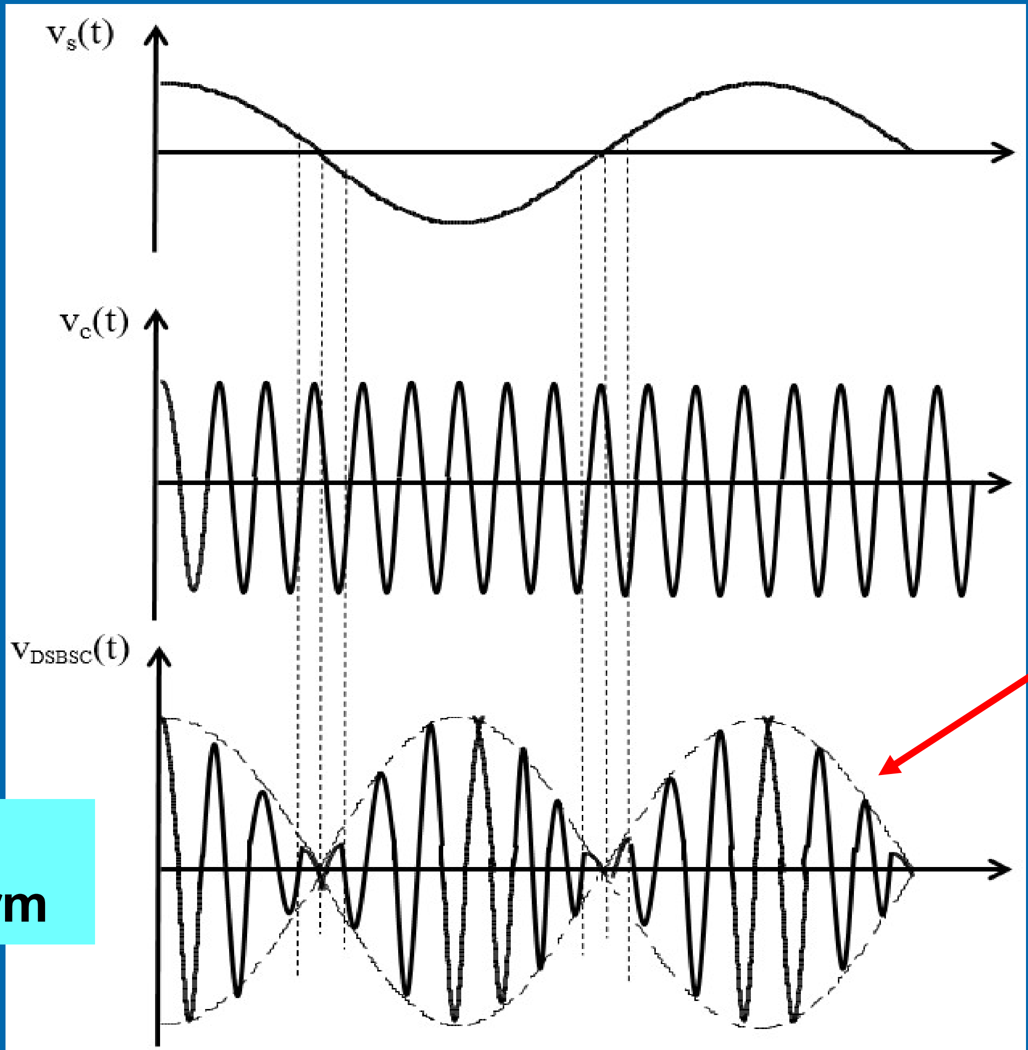


180^o phase change

DSBSC waveform

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

The DSBSC waveform for a sinusoidal modulating signal



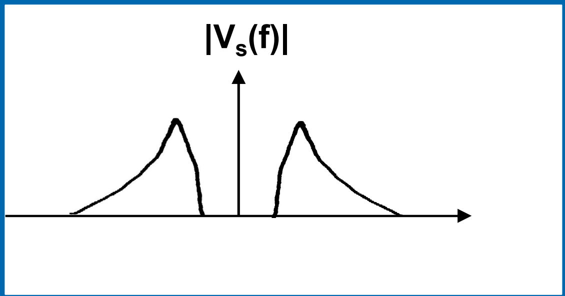
DSBSC waveform

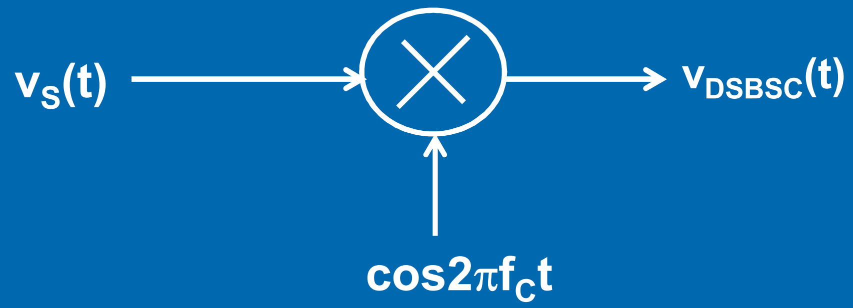
The envelope is not a faithful representation of the modulating signal.

Demodulation of DSBSC signal requires a complex demodulator.

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Frequency domain representation of DSBSC signals





$v_s(t)\cos 2\pi f_c t$

Standard equation for DSBSC signals

$$v_{AM}(t) = v_s(t) \times \cos 2\pi f_c t \quad \overset{FT}{\Longleftrightarrow} \quad V_{AM}(f) = \frac{1}{2}\left[V_s(f + f_c) + V_s(f - f_c) \right]$$

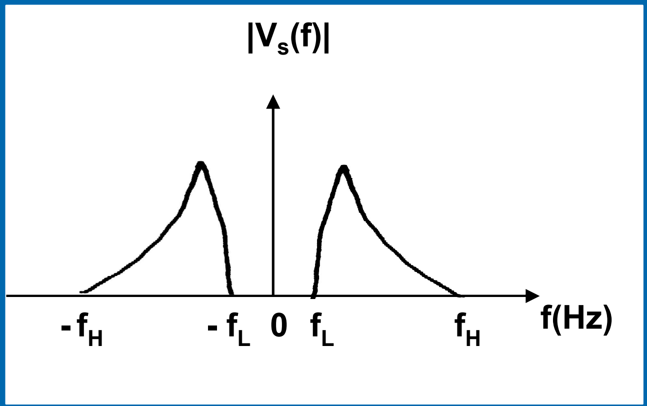
Shift $V_s(f)$ left by f_c

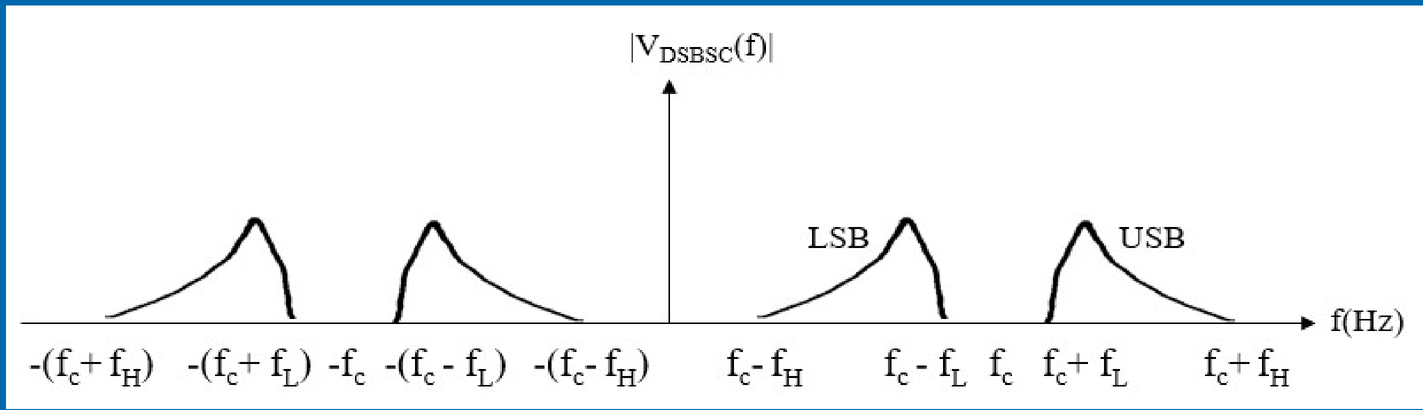
Shift $V_s(f)$ right by f_c

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Frequency domain representation of DSBSC signals

Spectrum of DSBSC signal





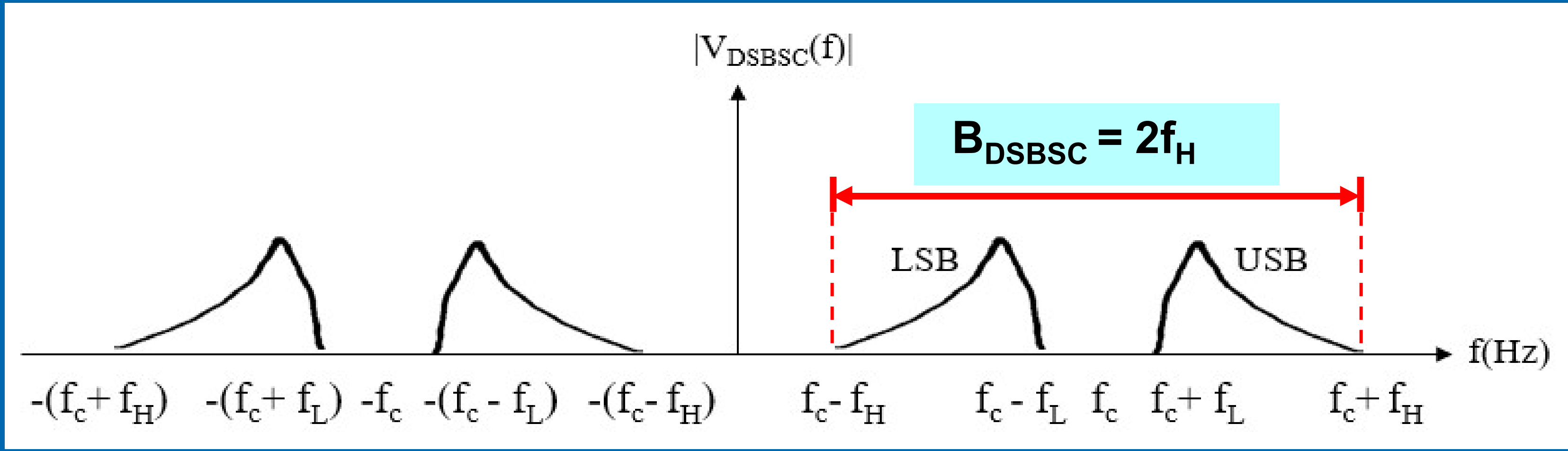
Multi-tone modulating signals

Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right by f_c

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

<u>**Frequency domain representation of DSBSC signals**</u>



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

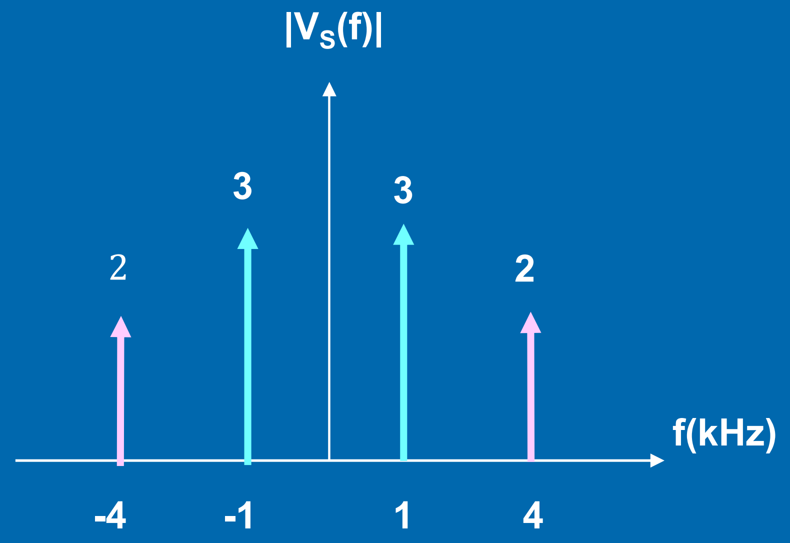
Example 5.5

The modulating signal in a DSBSC modulator is $v_s(t) = 4\cos 2000\pi t + 6\cos 8000\pi t$. The carrier signal is $v_c(t) = \cos(8 \times 10^5 \pi t)$. Plot the double-sided spectrum of the modulated signal.

Solution

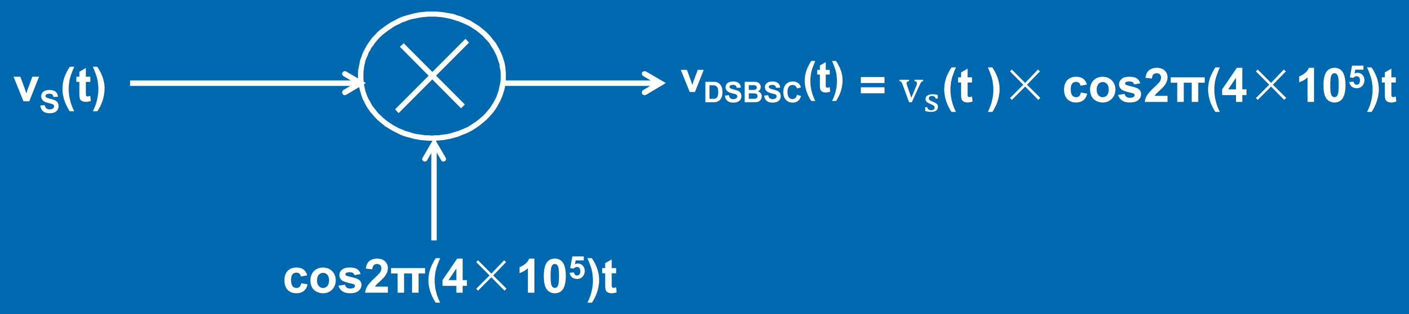
Spectrum of modulating signal

$v_s(t) = 6\cos 2000\pi t + 4\cos 8000\pi t$



Solution

$v_s(t) = 6\cos 2000\pi t$
$\quad + 4\cos 8000\pi t$



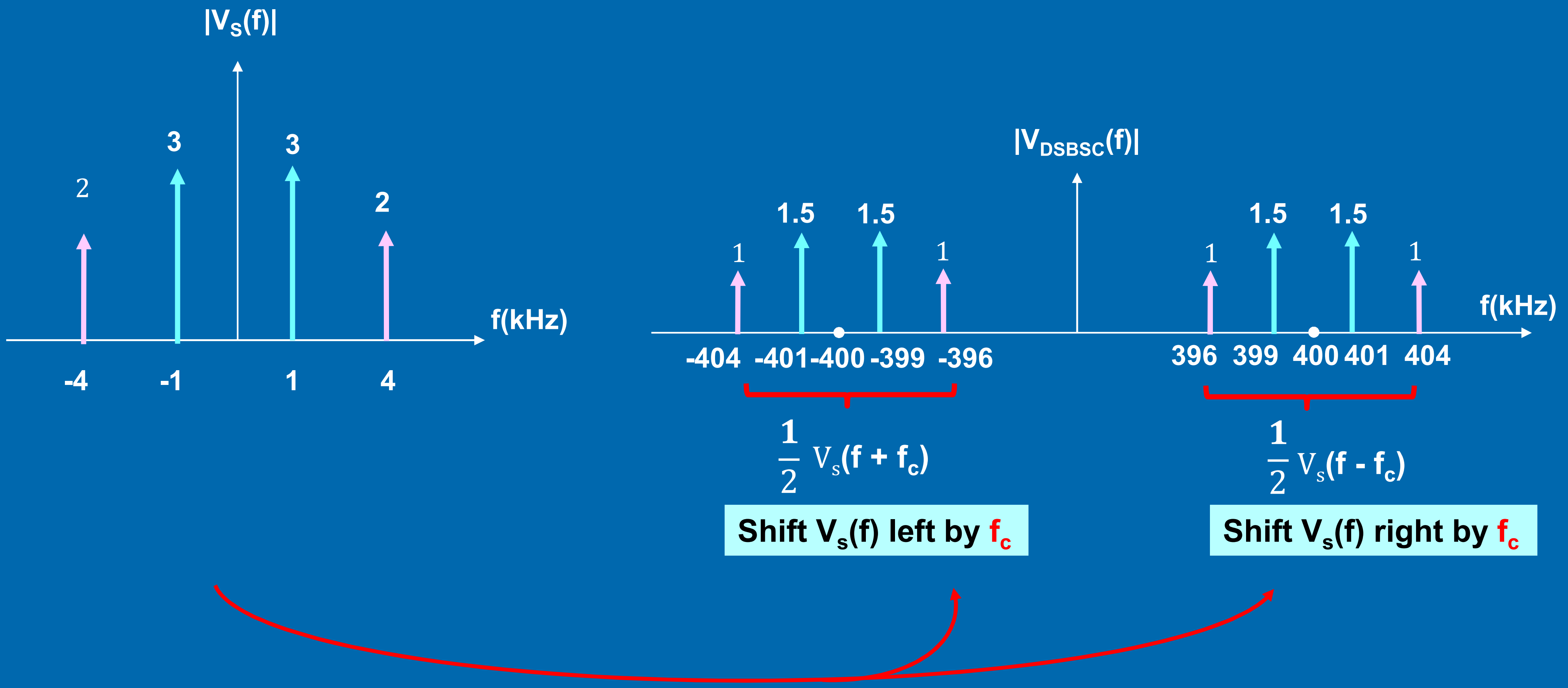
Standard equation for DSBSC signals

$$v_{AM}(t) = v_s(t) \times \cos 2\pi f_c t \quad \xleftrightarrow{FT} \quad V_{AM}(f) = \frac{1}{2}[V_s(f + f_c) + V_s(f - f_c)]$$

Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right to f_c

Solution



|Vs(f)|
2
3
3
2
f(kHz)
-4
-1
1
4
|VDSBSC(f)|
1
1.5
1.5
1
1
1.5
1.5
1
f(kHz)
-404 -401-400 -399 -396
396 399 400 401 404
$\frac{1}{2}V_s(f + f_c)$
$\frac{1}{2}V_s(f - f_c)$
Shift V_s(f) left by f_c
Shift V_s(f) right by f_c

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

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Single-Sideband (SSB) modulation

- There are three methods to produce SSB signals:

1. Filter method
   - Generate DSBSC signal
   - Extract one sideband

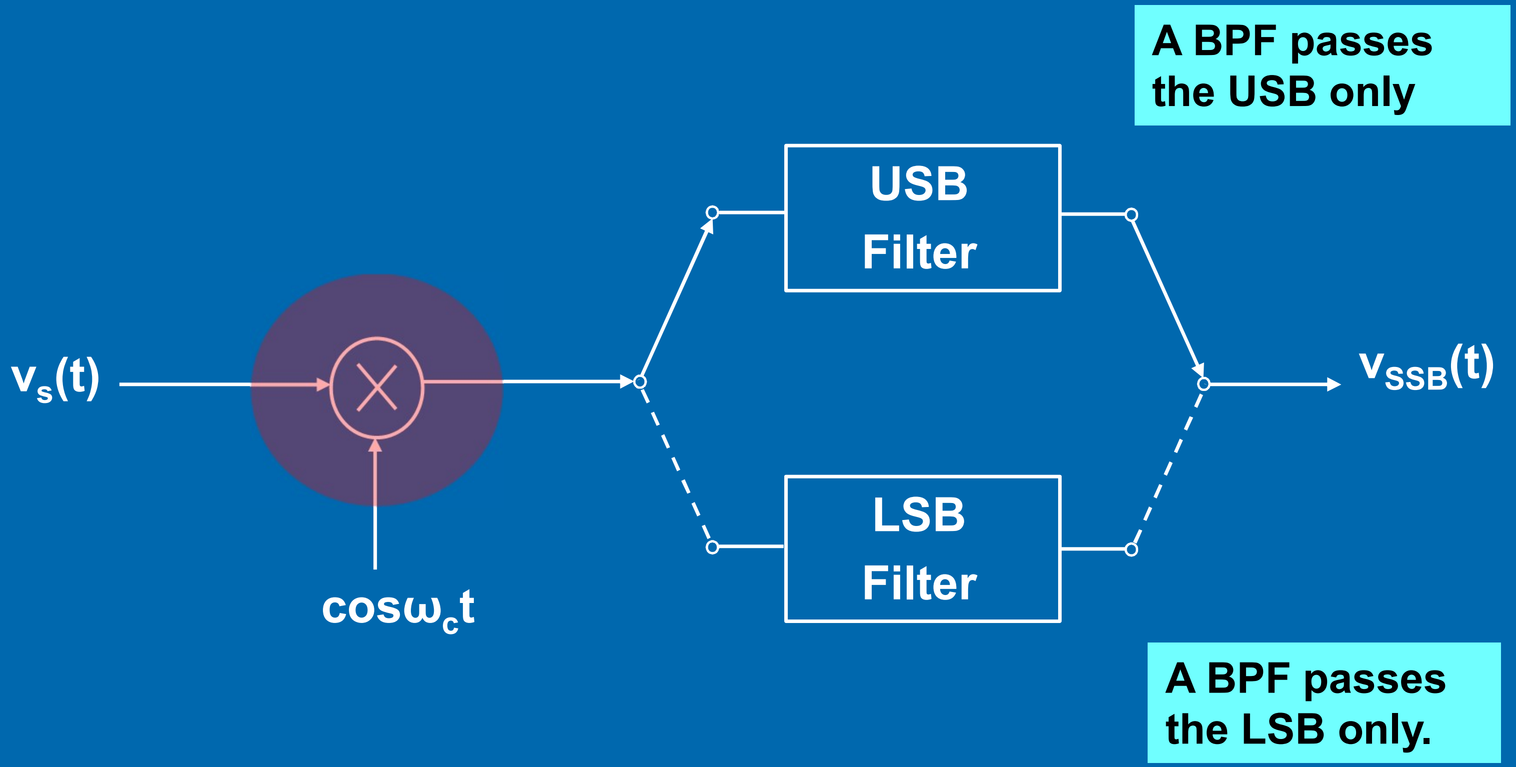
2. Phase shift method (not in syllabus)
   - Generate DSBSC signal
   - Attenuate unwanted sideband by cancelling

3. Weaver or third method (not in syllabus)
   - Generate DSBSC signal
   - filtering and cancellation

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

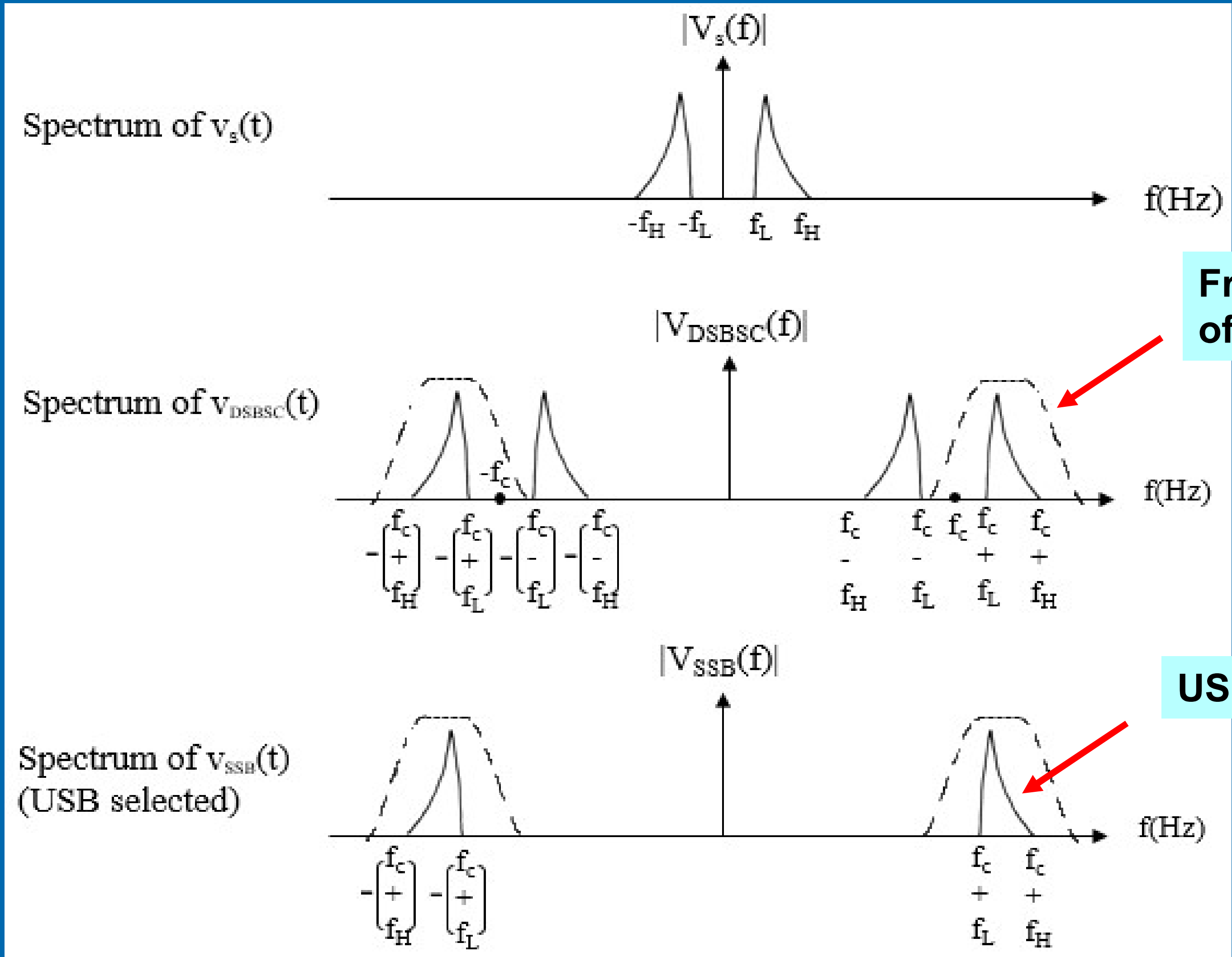
Single-Sideband (SSB) modulation

- **Generating SSB Signals using Filter Method**



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Single-Sideband (SSB) modulation



Frequency response of USB filter

USB is transmitted

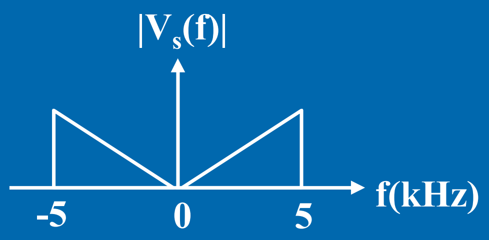
SSB signal spectrum

Example 5.6

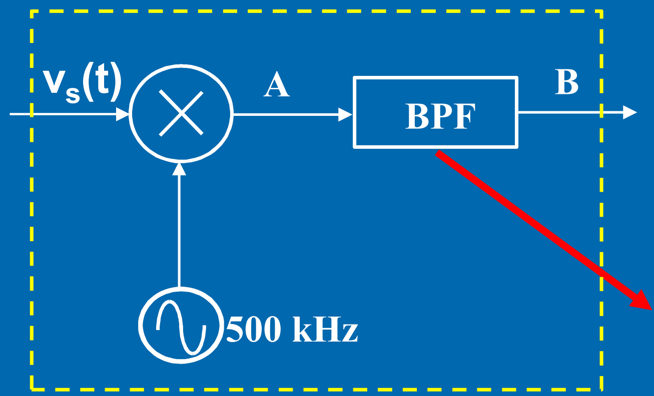
The frequency response of a BPF is shown below.

(a) Sketch the double-sided magnitude spectrum at point A and B.

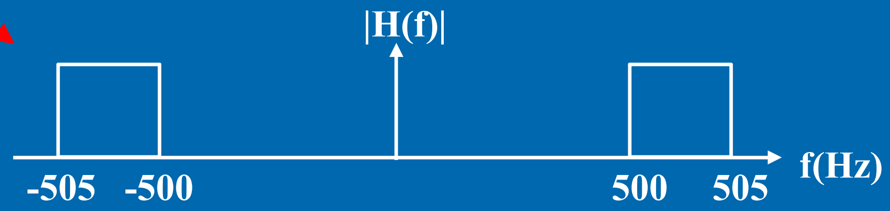
(b) What is the function of the block diagram?



Block diagram

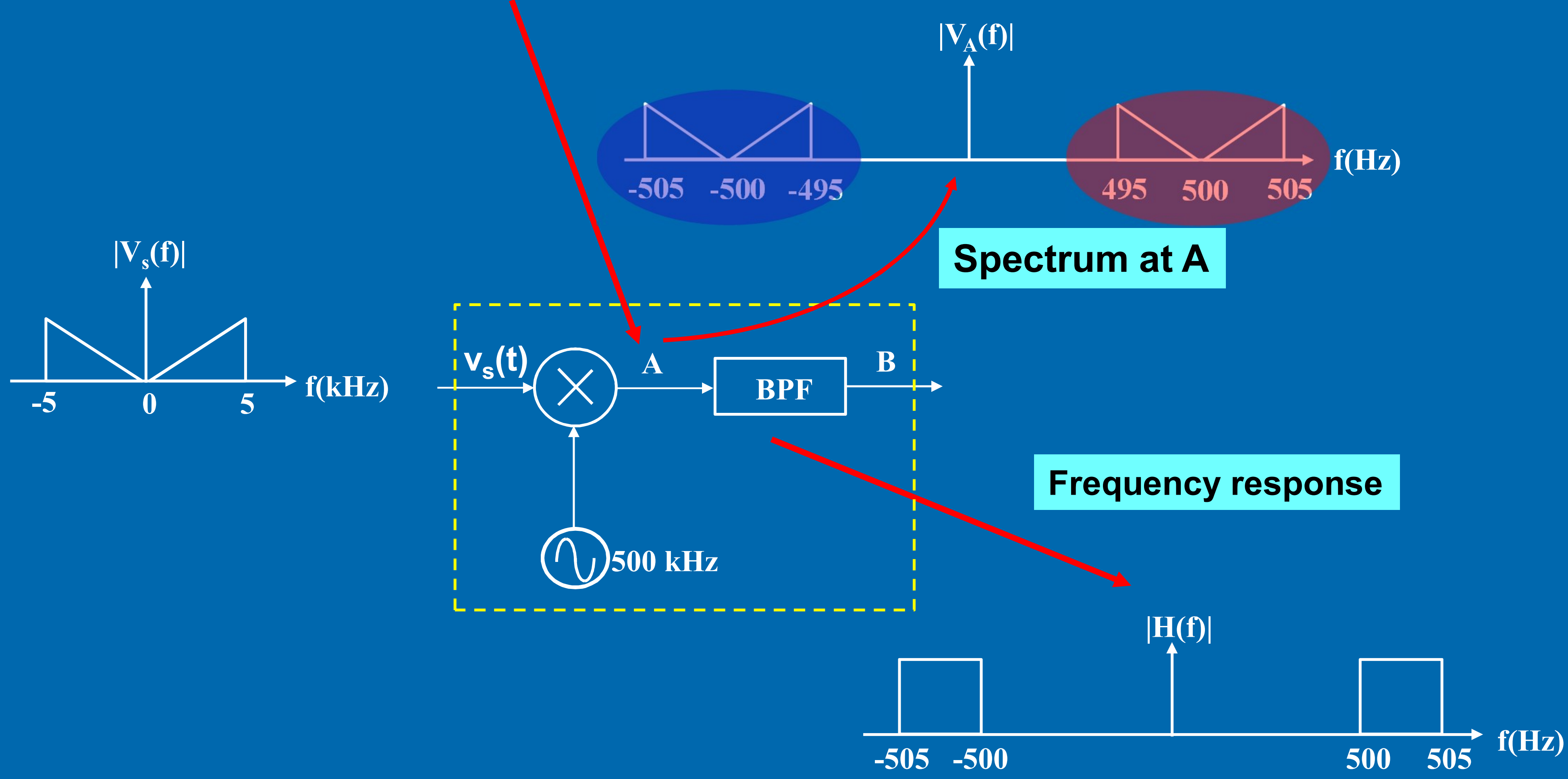


Frequency response of BPF



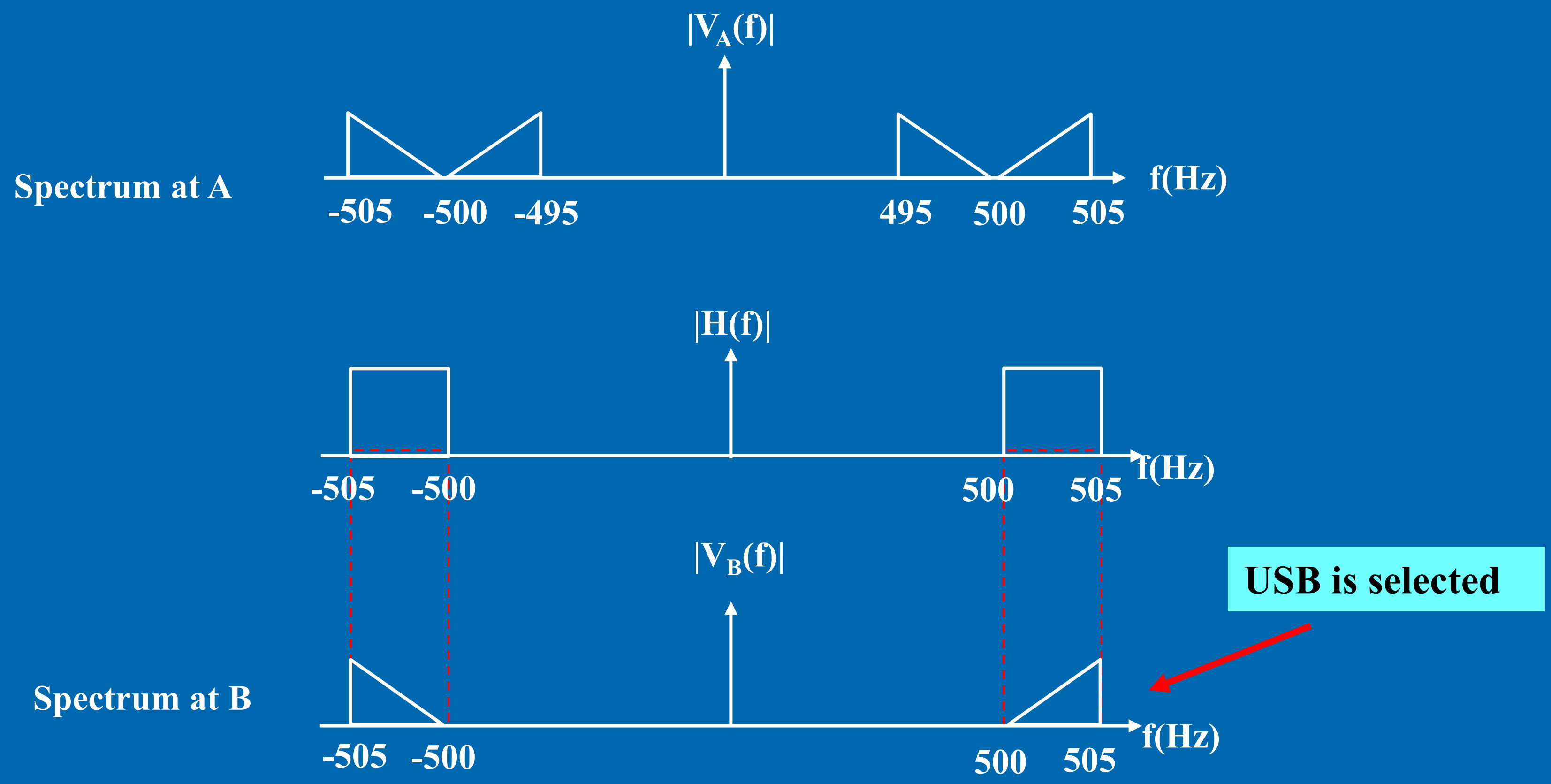
Solution

(a) $v_A(t) = v_s(t) \times \cos 2\pi(500 \times 10^3)t \quad \overset{FT}{\Longleftrightarrow} \quad V_A(f) = \frac{1}{2}[V_s(f + f_c) + V_s(f - f_c)]$



Solution

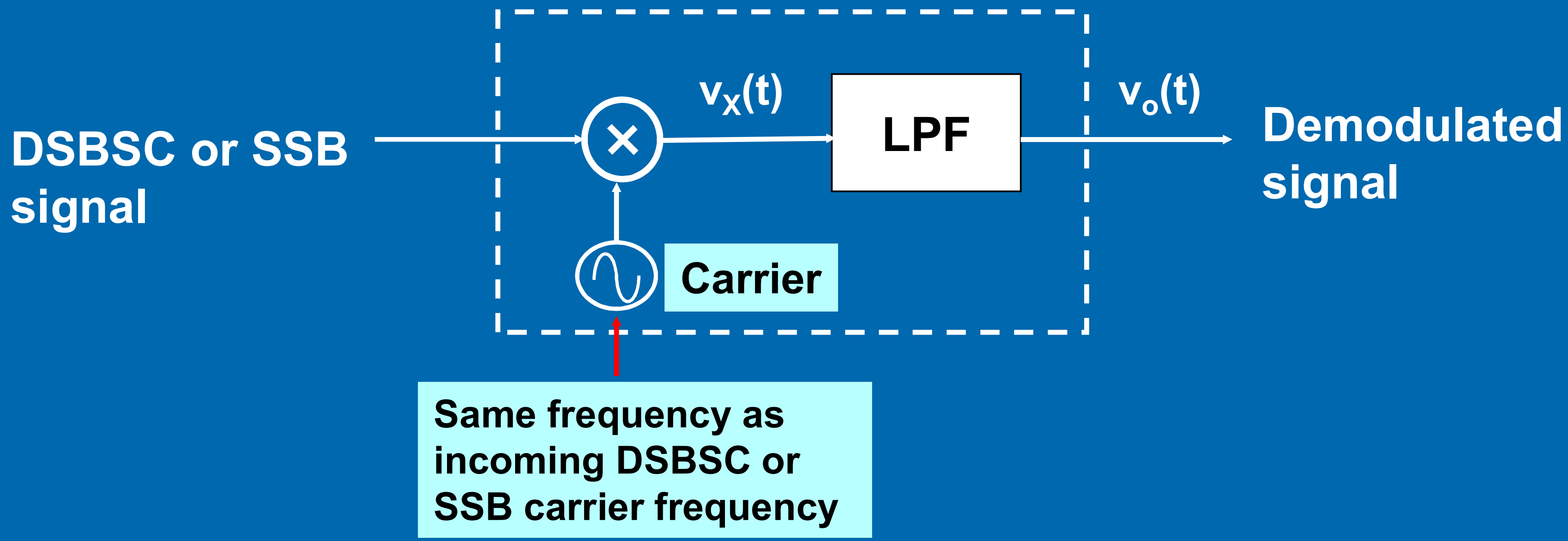
(a)



(b) **SSB modulator**

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

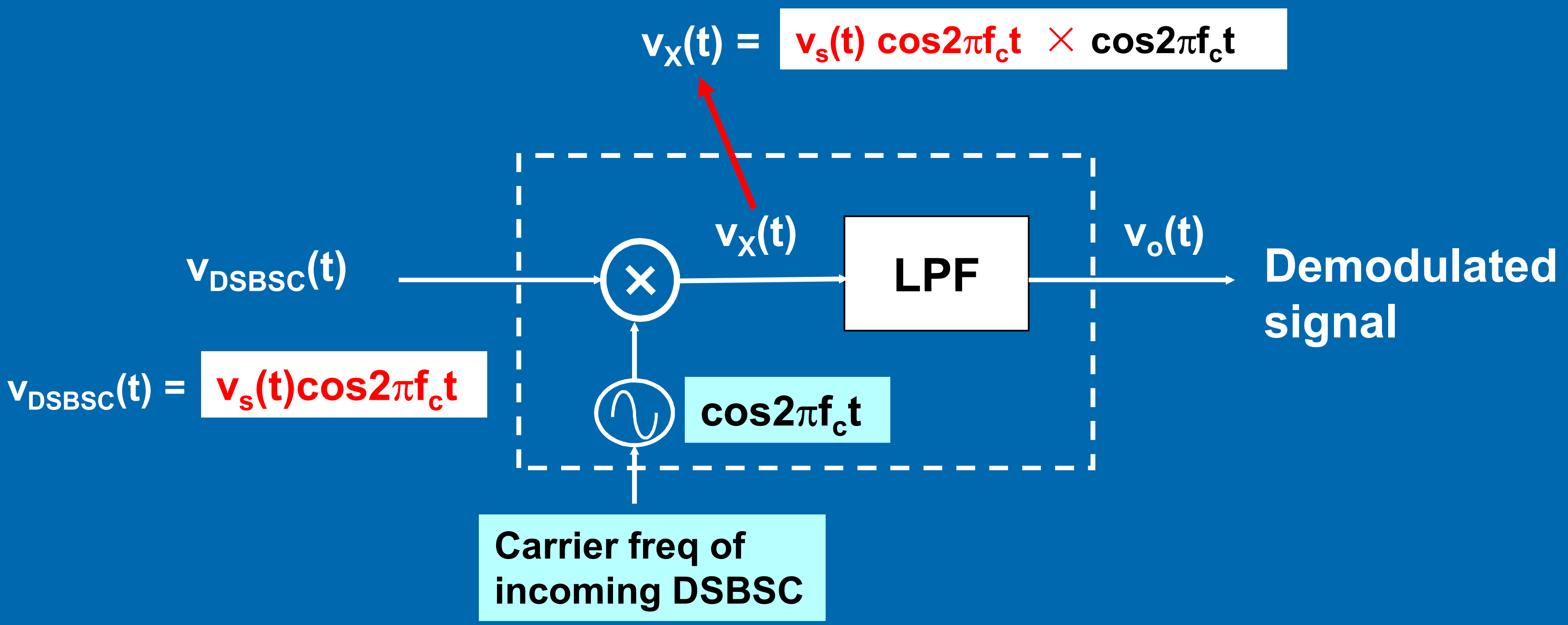
DSBSC and BSS demodulators



Circuit also known as Synchronous Detector

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

<u>DSBSC and BSS demodulators</u>



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

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DSBSC and BSS demodulators

Fourier transform

$v_{DSBSC}(t) \quad \xleftrightarrow{FT} \quad V_{DSBSC}(f)$

$$v_{DSBSC}(t) \times \cos 2\pi f_c t \quad \xleftrightarrow{FT} \quad V_X(f) = \frac{1}{2}[\,V_{DSBSC}(f + f_c) + V_{DSBSC}(f - f_c)\,]$$

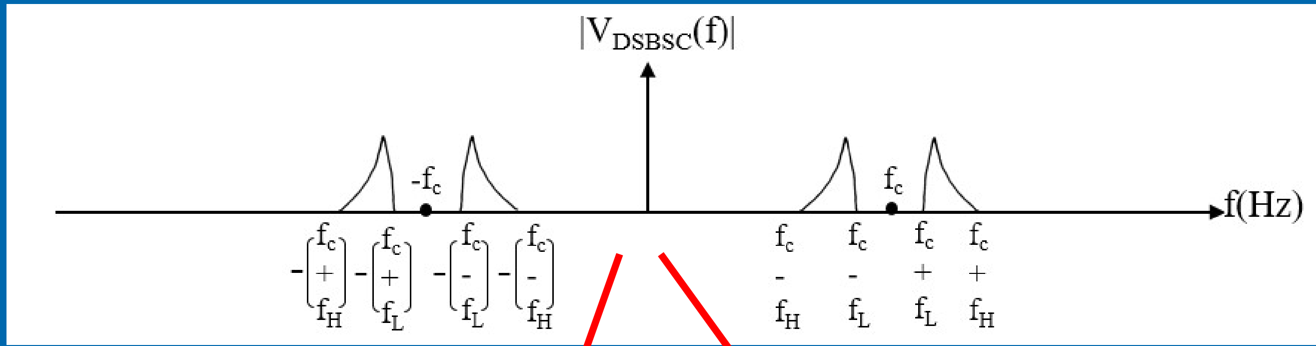
Shift V_{DSBSC} (f) left by f_c

Shift V_{DSBSC} (f) right by f_c

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

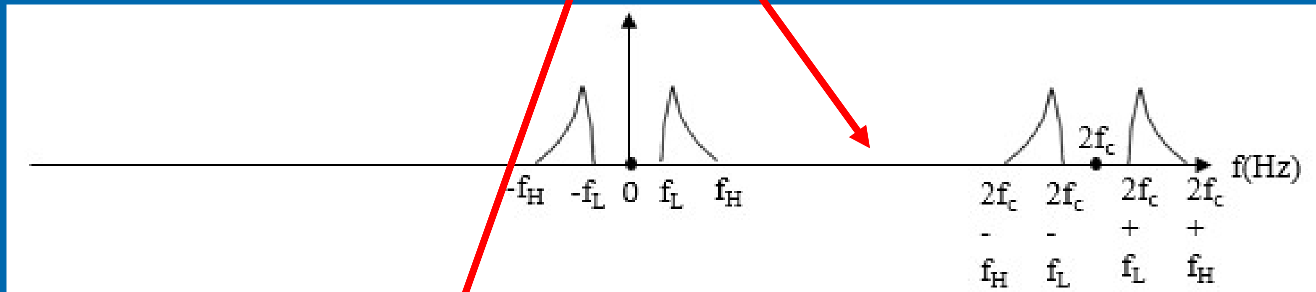
DSBSC and BSS demodulators

$V_{DSBSC}(f)$



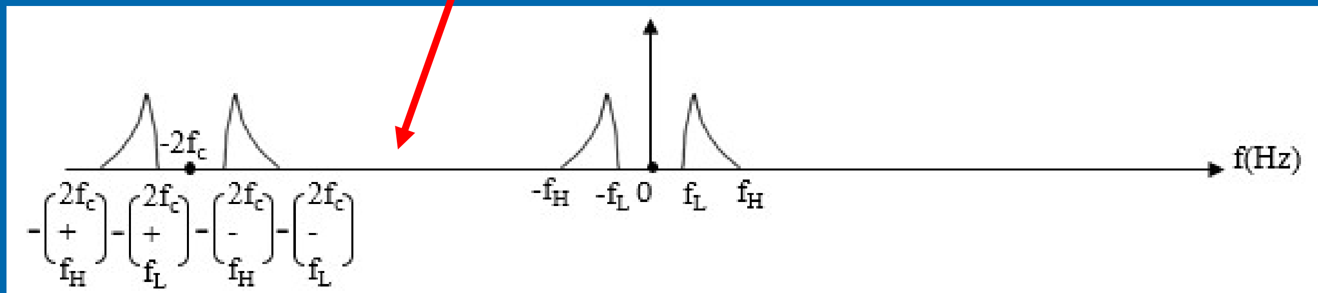
$\frac{1}{2}[V_{DSBSC}(f - f_c)]$

Shift V_{DSBSC} (f) right by f_c



$\frac{1}{2}[V_{DSBSC}(f + f_c)]$

Shift V_{DSBSC} (f) left by f_c



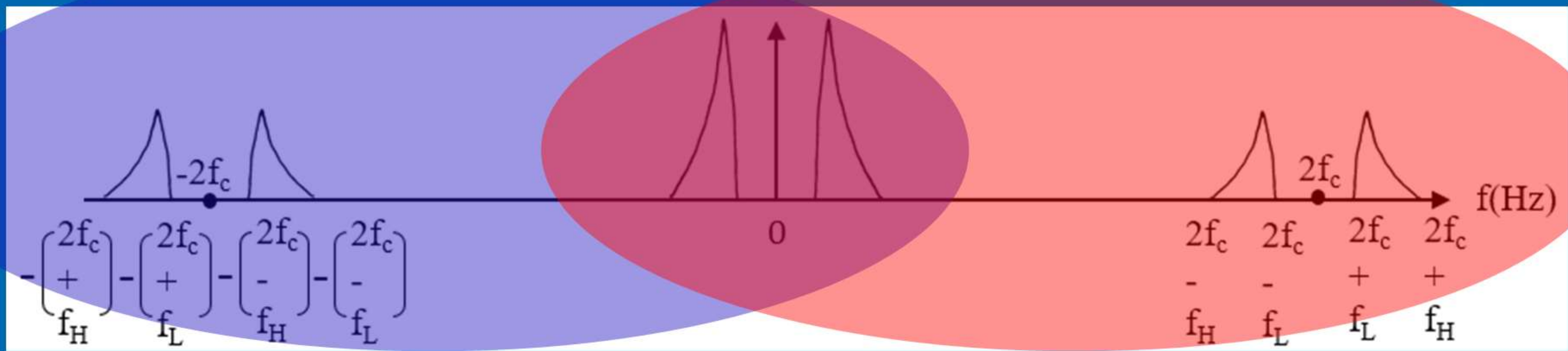
5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

DSBSC and BSS demodulators

$V_X(f) = \frac{1}{2}[V_{DSBSC}(f + f_c) + V_{DSBSC}(f - f_c)]$

Spectrum of the signal $v_x(t)$

$|V_x(f)|$



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

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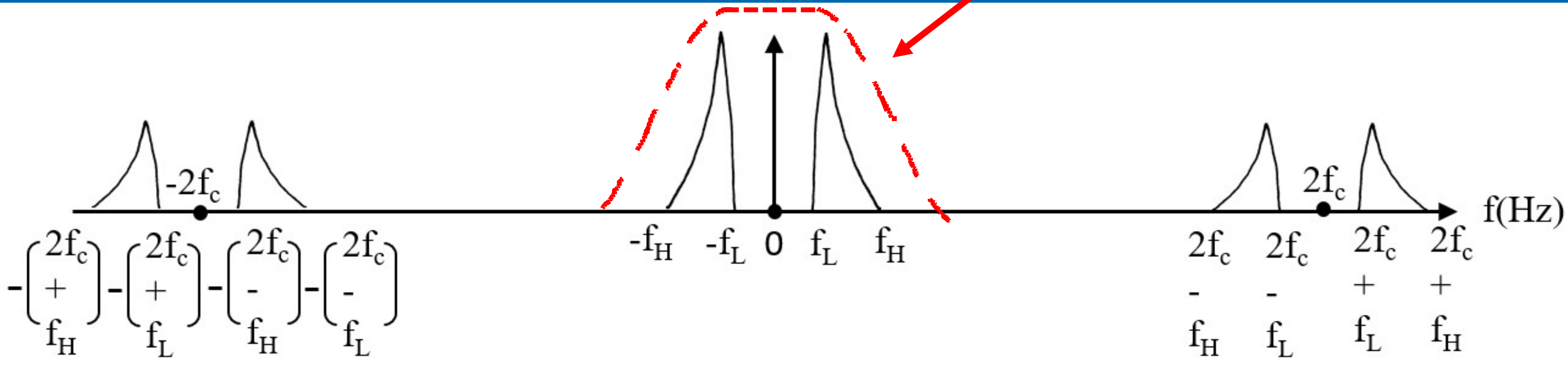
DSBSC and BSS demodulators

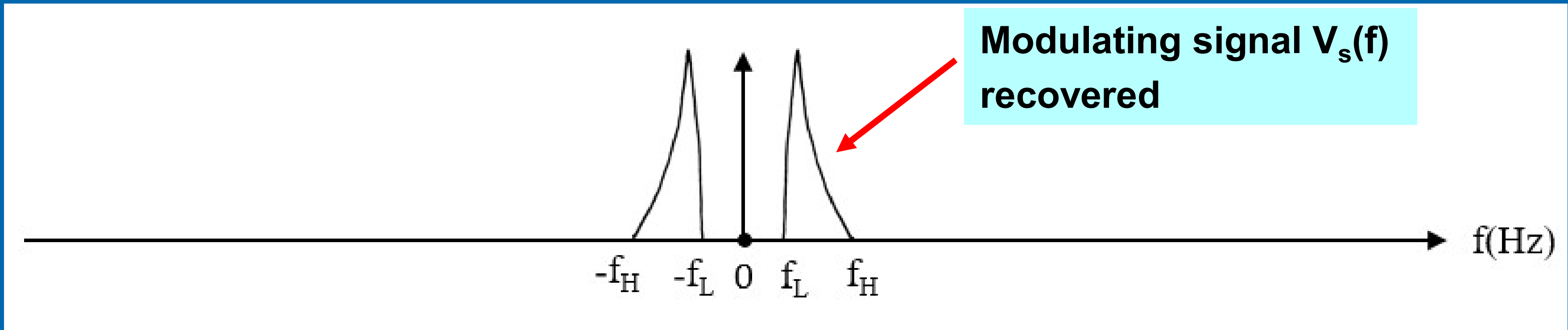
$V_X(f) = \frac{1}{2}[\, V_{DSBSC}(f + f_c) + V_{DSBSC}(f - f_c)\,]$

Frequency response of LPF



$V_o(f) = V_s(f)$

Modulating signal $V_s(f)$ recovered



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Advantages and Disadvantages of DSBSC and SSB

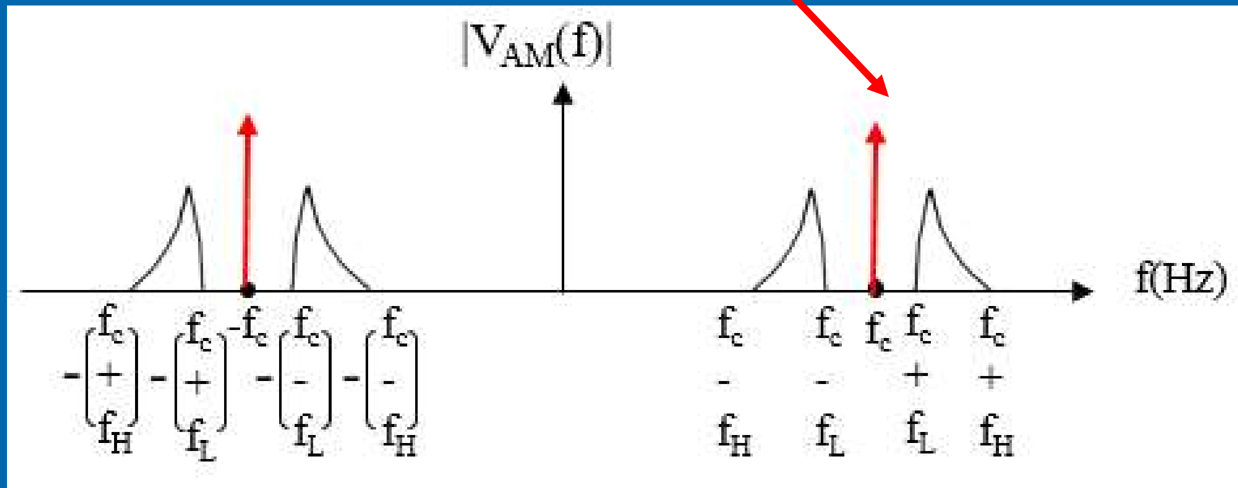
Advantages of DSBSC and SSB compared with AM:

- **Power Saving**

DSBSC: total power saving > 67%.

SSB: total power saving > 84% (67% + 17%)

Carrier component takes up > 67% of total transmission power.



SSB power is half that of DSBSC.

Each sideband takes up < 17% of total transmission power.

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

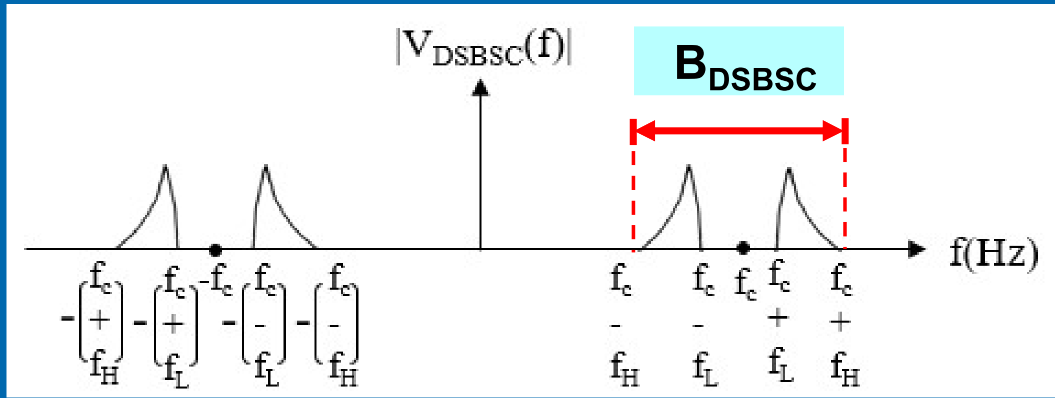
Advantages and Disadvantages of DSBSC and SSB

Bandwidth of DSBSC signal same as AM.

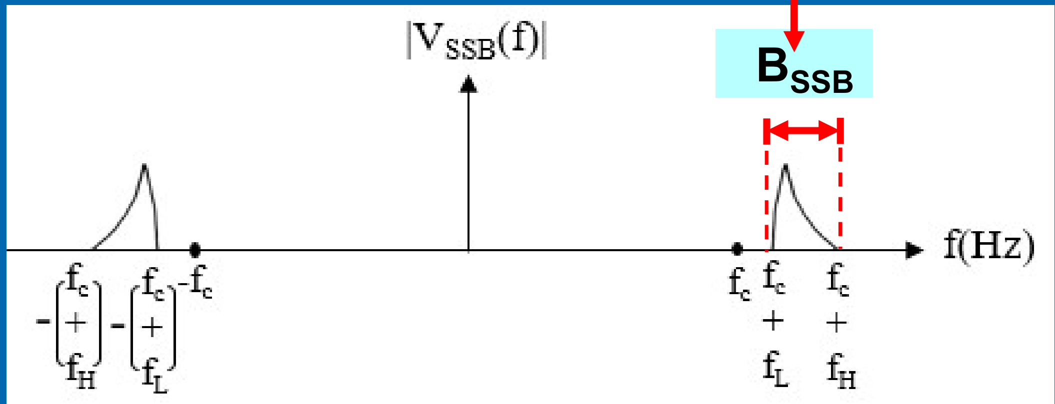
Advantages of SSB

- **Bandwidth Saving**

SSB: bandwidth reduction = 50%



Bandwidth of SSB signal < that of AM and DSBSC.



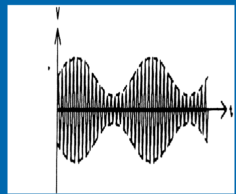
5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

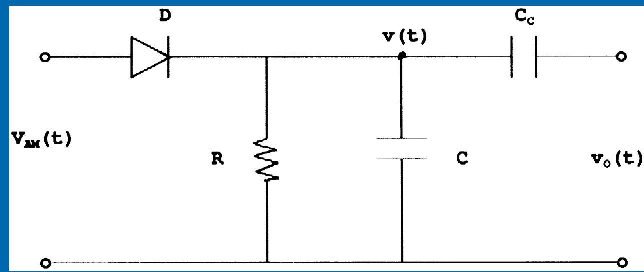
Advantages and Disadvantages of DSBSC and SSB

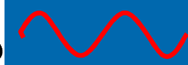
Disadvantages of DSBSC and SSB

More sophisticated demodulators used

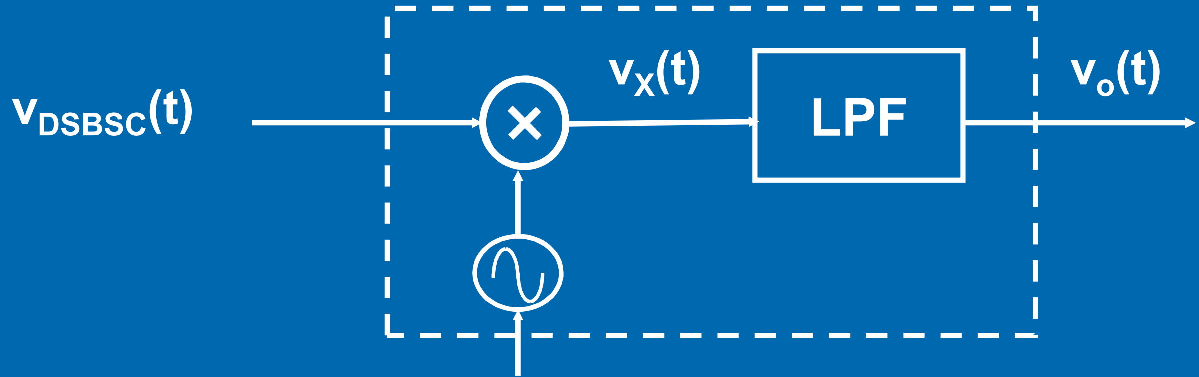
AM demodulator
Envelope Detector







DSBSC/SSB demodulator
Synchronous Detector

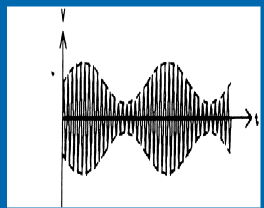


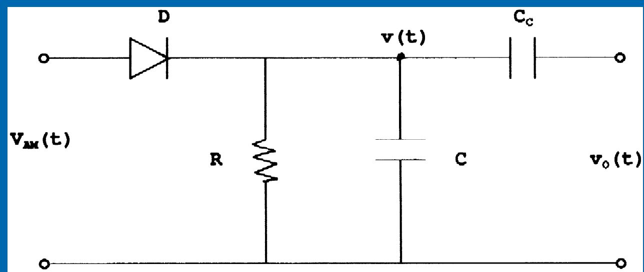
5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

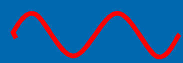
Applications of AM, DSBSC and SSB

Application of AM

Type of Modulation	Advantage	Application
AM	Cheap demodulator	Radio broadcasting







5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

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Applications of AM, DSBSC and SSB

Applications of SSB

Type of Modulation	Advantages	Applications
SSB	Lowest bandwidth	FDM in Telephone system
	Lowest power wastage	Battery powered transmitters

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

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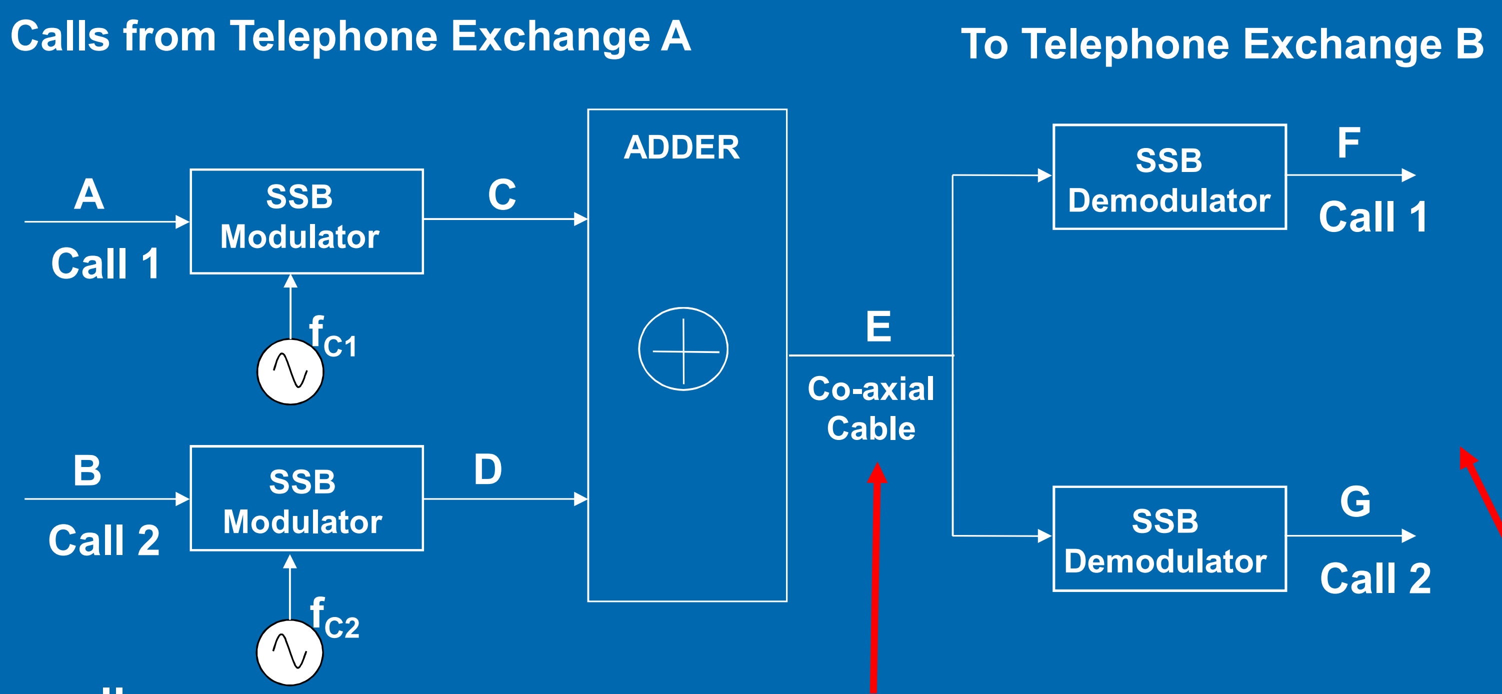
Applications of AM, DSBSC and SSB



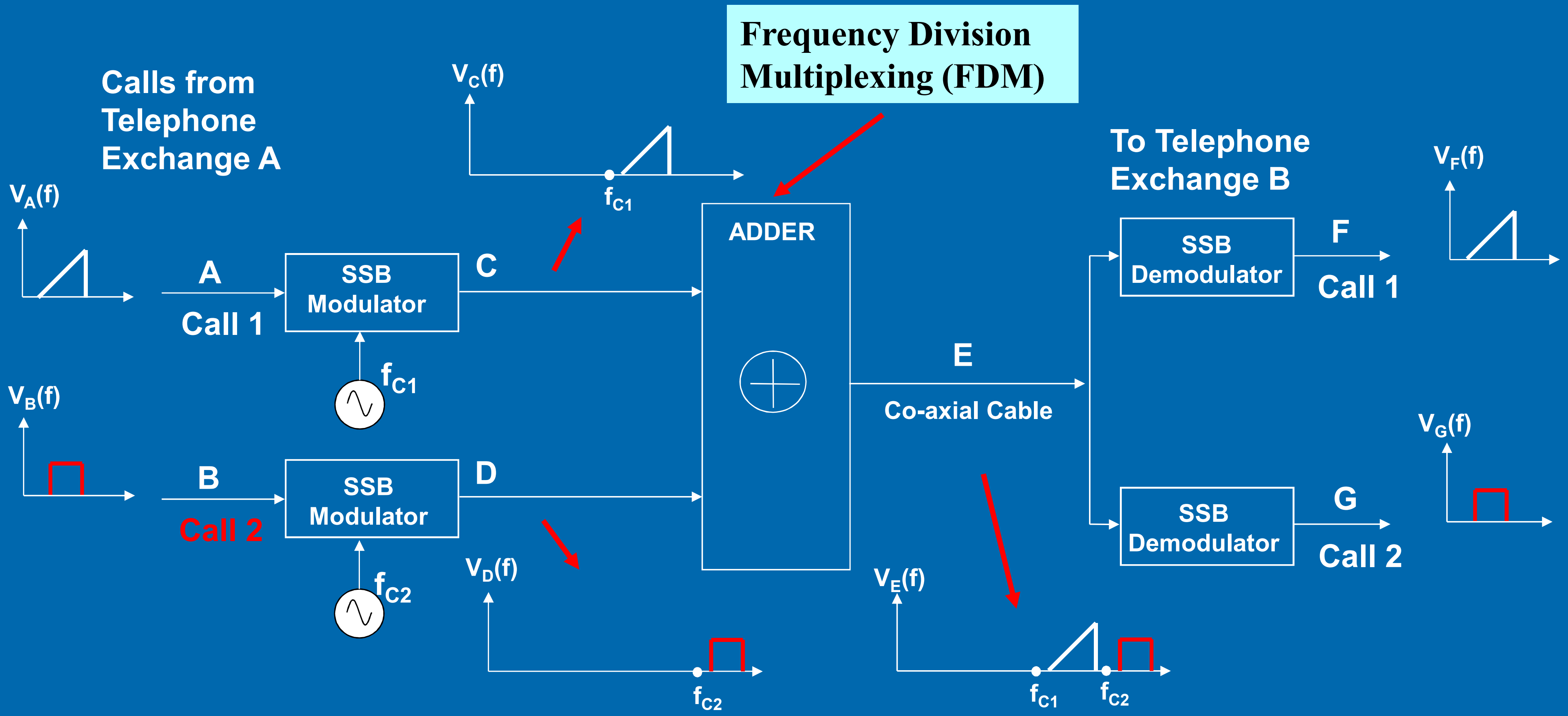
Only 2 telephone calls are shown for illustration but in practice, there are thousands of calls.

All the telephone calls from Exchange A are combined into one signal and carried over one cable.

The telephone calls are separated out at Exchange B.

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Applications of AM, DSBSC and SSB



5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

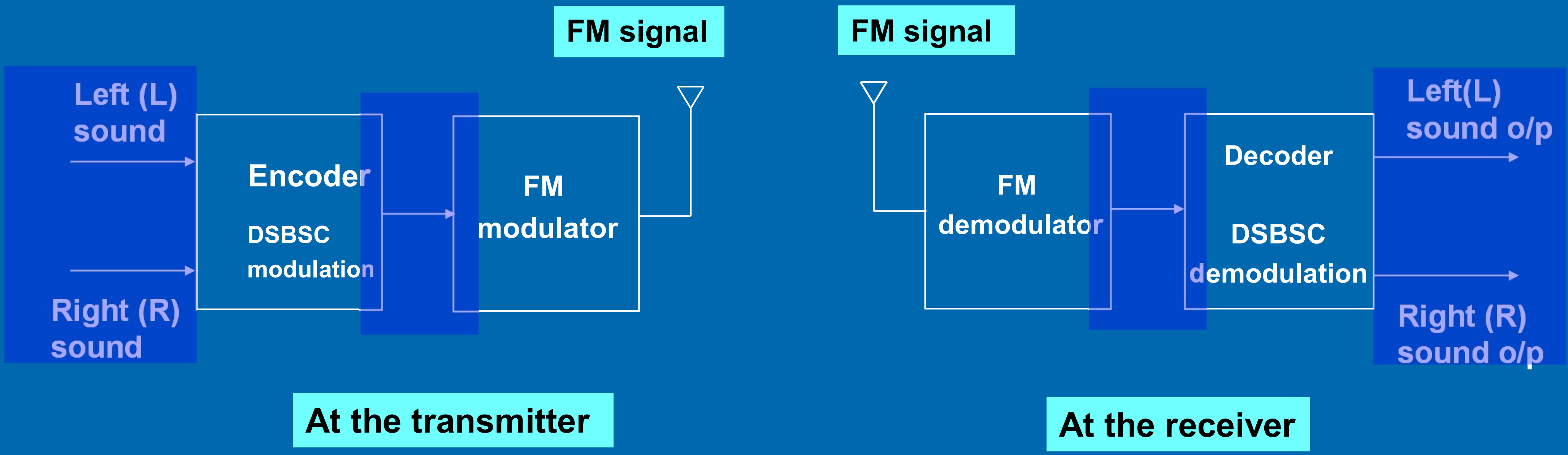
Applications of AM, DSBSC and SSB

Type of Modulation	Advantages	Applications
DSBSC	Simpler to generate than SSB	Combine L + R audio channels in FM Stereo
	Lower power wastage than AM	Combine R + G + B colour channels in TV broadcasting

5.4 Double sidebands suppressed carrier (DSBSC) and Single-Sideband (SSB) modulation

Applications of AM, DSBSC and SSB

Combining L + R audio channels in FM Stereo



End

CHAPTER 5

(Part 4 of 4)