Double Sideband Suppressed Carrier (DSBSC)

Complex Envelope Representation

Theorem: Any physical bandpass waveform can be represented as

\[ v(t) = \text{Re} \left\{ g(t) e^{j \omega_c t} \right\} \]

\[ = \frac{g(t) e^{j \omega_c t} + g^*(t) e^{-j \omega_c t}}{2} \]

\[ = R(t) \cos(\omega_c t + \phi(t)) \]

where \( R(t) = |g(t)| \) and \( \phi(t) = \angle g(t) \)
for $g(t)$ being real then $N(t) = g(t) / \cos \omega_c t$  \(2-0.9\)

Represent $g(t) = X(t) + jY(t)$

then $X(t) = ''$in-phase'' component$

$Y(t) = ''$quadrature'' component$.

terminology $g(t)$ modulates $N(t)$

Consider a modulation technique called

DSBSC  \(\text{Dwójna symetryczna} \)  \(\text{z dodatnim} \)  \(\text{cofkaczem} \)

Consider a ''message'' signal $g_m(t)$

The carrier to be modulated is

$S_c(t) = A_c \cos 2\pi f_c t$
The modulated signal is
\[ s(t) = g_m(t) s_c(t) \]

The DSBSC modulator

\[ g_m(t) \quad \xrightarrow{\text{\times}} \quad s(t) \]

Let \( G_m(f) = \)

\[ \frac{1}{2} \left[ s(f-f_c) + s(f+f_c) \right] \]

Assume "narrowband" modulation which requires \( B \ll f_c \)

then \( S(f) = G_m(f) \ast S_c(f) \)

\[ = G_m(f) \ast \left[ \frac{1}{2} s(f-f_c) + s(f+f_c) \right] \]

\[ = (G_m(f-f_c) + G_m(f+f_c))/2 \]
Graphically

\[ G_m(f + f_c) \]

\[ \frac{G_m(f + f_c)}{2} \]

\[ \frac{G_m(f - f_c)}{2} \]

USB

LSB

\( f \)

\( f_c - B \)

\( f_c + B \)

\( f_c \)

Lower sideband

Upper sideband

Note, no carrier
Monotonic Analysis

Let \( g_m(t) = \cos 2\pi ft + \chi \cos 2\pi ft \) 

\[ g_m(t) = \gamma \] 

\[ S(f) = \frac{1}{2} \left( S(f-f_m) + S(f+f_m) \right) \] 

Where \( s(t) = g(t) \)
The modulated waveform is DSBSC

Demodulation

\[ \hat{g}_m(t) = [s(t) \ s_c(t)] * h_{LP}(t) \]

Why does this work?

\[ y(t) = s(t) \ s_c(t) = g_m(t) \ s_c(t) \ s_c(t) = g_m(t) \ s_c^2(t) \]
so for \( s(t) = A_c \cos 2\pi f_c t \)

\[
y(t) = g_m(t) A_c^2 \cos^2 (2\pi f_c t) = g_m(t) A_c^2 \left(1 + \cos 4\pi f_c t \right) \]

in the FT domain

\[
Y(f) = A_c^2 G_m(f) * \left[ \frac{\delta(f)}{2} + \frac{\delta(f-2f_c) + \delta(f+2f_c)}{4} \right]
\]

Graphically (Assume \( A_c = 1 \) for simplicity)
**ORDERING INFORMATION**

<table>
<thead>
<tr>
<th>Device</th>
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<tr>
<td>MC1496G</td>
<td>0°C to +70°C</td>
<td>Metal Can</td>
</tr>
<tr>
<td>MC1496L</td>
<td>0°C to +70°C</td>
<td>Ceramic DIP</td>
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<tr>
<td>MC1496P</td>
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**BALANCED MODULATOR — DEMODULATOR**

- Designed for use where the output voltage is a product of an input voltage (signal) and a switching function (carrier).
- Typical applications include suppressed carrier and amplitude modulation, synchronized detection, FM detection, phase detection, and chopper applications. See Motorola Application Note AN-531 for additional design information.
- Excellent Carrier Suppression — 85 dB typ @ 0.5 MHz
- 50 dB typ @ 10 MHz
- Adjustable Gain and Signal Handling
- Balanced Inputs and Outputs
- High Common-Mode Rejection — 85 dB typ

**FIGURE 1 — SUPPRESSED-CARRIER OUTPUT WAVEFORM**

**FIGURE 2 — SUPPRESSED-CARRIER SPECTRUM**

**FIGURE 3 — AMPLITUDE-MODULATION OUTPUT WAVEFORM**

**FIGURE 4 — AMPLITUDE-MODULATION SPECTRUM**

**MC1496 MC1596**

**BALANCED MODULATOR — DEMODULATOR**

**SILICON MONOLITHIC INTEGRATED CIRCUIT**

**G SUFFIX METAL PACKAGE CASE 603**

**L SUFFIX CERAMIC PACKAGE CASE 603 TO-115**

**P SUFFIX PLASTIC PACKAGE CASE 645 (MC1496 only)**
Total Harmonic Distortion and Intermodulation Distortion (IMD)

Given an input signal $V_i(t) = A_0 \sin \omega_0 t$

The second order distortion output is

$$K_2 (A_0 \sin \omega_0 t)^2 = K_2 \frac{A_0^2}{2} (1 - \cos 2\omega_0 t)$$

In general

$$V_{out}(t) = V_0 + V_1 \cos (\omega_0 t + \phi) + V_2 \cos (2\omega_0 t + \phi) + \ldots$$

where $V_n$ is peak value at $n \omega_0 hz$ where $2\pi f_0 = \omega_0$
THD (\%o) = \sqrt{\sum_{n=2}^{\infty} \frac{N_n^2}{N_1}} \times 100\%_o

Experimentally, use a distortion analyzer or a spectrum analyzer.

Intermodulation Distortion (IMD)

\[ V_i(t) = A_1 \sin \omega_1 t + A_2 \sin \omega_2 t \]

Consider \( K_3 N_i^3 = K_3 (A_1 \sin \omega_1 t + A_2 \sin \omega_2 t)^3 \)

(All Couch, Eq. 4.49)

\( = K_3 \left( A_1^3 \sin^3 \omega_1 t + 3 A_1^2 A_2 \sin^2 \omega_1 t \sin \omega_2 t + 3 A_1 A_2^2 \sin \omega_1 t \sin^2 \omega_2 t + A_2^3 \sin^3 \omega_2 t \right) \)

(All Couch, Eq. 4.50)

\[ \frac{3}{2} K_3 A_1 A_2 \sin \omega_2 t = \frac{1}{2} (\sin (2\omega_2 + \omega_1) t - \sin (2\omega_2 - \omega_1) t) \]

\( \frac{3}{2} K_3 A_1 A_2 \sin \omega_2 t \)
\[
\frac{3}{2} K_3 A_1 A_2 \sin \omega_1 t - \frac{1}{2} \left[ \sin (2\omega_1 + \omega_2) t - \sin (2\omega_2 - \omega_1) t \right] \]

\[
\text{IMD}
\]

\[
2\omega_1 - \omega_2 \approx \omega_1, \omega_2
\]

\[
R \text{ IMD} = \frac{4}{3} \left( \frac{K_1}{K_3 A^2} \right) \text{ where } A_1 = A_2 = A
\]

desired output is \( K_1 A \)

3rd order IMD output

\[
3 \frac{K_3 A^3}{4}
\]