EE 357- Communication Systems

Laboratory Session 2 - Frequency Modulation

OBJECTIVE : Investigate Frequency Modulation

THEORY:

Modulation

FM signal can be mathematically represented as,

$$X_{FM}(t) = A_c \cos\left(\omega_c t + 2\pi k_f \int x_m(t)dt\right) \qquad \text{.......................................(1)}$$

For single tone modulation,

$$X_{FM}(t) = A_c \cos\left(\omega_c t + 2\pi\, k_f \int A_m \cos(\omega_m t)\, dt\right)$$
$$= A_c \cos\left(\omega_c t + 2\pi\, \Delta f \int \cos(\omega_m t)\, dt\right)$$
$$= A_c \cos\left(\omega c\, t + \beta \sin(\omega_m t)\right) \qquad \text{.......................................(2)}$$

Where;

K_f - Sensitivity of the function generator

$x_m(t)$ - Modulating signal

Δf - Peak frequency deviation

β – Modulation Index

Using the Bessel function it can be shown that,

$$X_{FM}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos(\omega_c + n\omega_m)\, t \qquad \text{.......................................(3)}$$

And

$$X_{FM}(f) = \frac{A_c}{2} \sum_{n=-\infty}^{\infty} J_n(\beta)\{\delta[f + (f_c + nf_m)] + \delta[f - (f_c + nf_m)]\} \qquad \text{.......................................(4)}$$

Total average power

Total average power of FM signal is given by

$$P_{av} = S_T = \sum_{n=-\infty}^{\infty} \frac{1}{2} A_c^2 J_n^2(\beta) \qquad \text{.......................................(5)}$$

Band width (BW)

Instantaneous frequency of FM signal is given by

$f_i = f_c + k_f\, m(t)$ ....(6)

According to Carson's rule, bandwidth of a FM signal is given by

BW = 2 fm (β + 1) …………………………………………………………………………………….........(7)

Frequency spectrum of the FM signal which correspond to a specific message signal can be changed by changing β value. As

$$\beta = \frac{k_f A_m}{f_m} \quad \text{..(8)}$$

by changing A_m, frequency spectrum of the FM signal is changed.

<u>MATLAB Exercise</u> **:**

<u>Part 1 : Generate different frequency modulated signal which has different frequency spectrums for the same message signal</u>

1. Generate a sinusoidal carrier signal with frequency 200 Hz and a sinusoidal message signal with frequency 10 Hz. (Select a suitable sampling time)
2. Using the Bessel function (Table 1), Identify the desired A_m values (using equation 8) that has to be set in order to get the following FM signal frequency spectrum cases.(Use K_f =1)
   a) Carrier only.
   b) Only the carrier and the 1st sideband pair are there.
   c) Only the carrier, 1st sideband pair and the 2nd sideband pair are there.
   d) Only the carrier, 1st sideband pair the 2nd sideband pair and 3rd sideband pair are there.
   e) Suppressed carrier.
   f) Suppressed 1st sideband pair.
3. Then generate the frequency spectrum of the FM signals (a) – (f) using the MATLAB function **fft.**
4. Plot the time series signals and the corresponding frequency spectrum of signals (a) – (f).

<u>Part 2 : Observe the effect of fm on the frequency spectrum</u>

For the case of β=4, change f_m (4 values) and observe the frequency spectrum of the FM signals and plot as in 4.

DISCUSSIONS :

1. Explain why FM is better than AM in terms of resistance to noise.
2. Describe two methods to estimate the occupied bandwidth of an FM signal.
3. Describe the key features of spectrum allocation used for typical FM radio broadcasting.
4. Compare the performance of FM and AM on the frequency spectrum.

Table 1: Bessel table

Beta	J(0)	J(1)	J(2)	J(3)	J(4)	J(5)	J(6)	J(7)	J(8)	J(9)	J(10)	J(11)	J(12)	J(13)	J(14)
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.25	0.9844	0.124	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0.9385	0.2423	0.0306	0	0	0	0	0	0	0	0	0	0	0	0
0.75	0.8642	0.3492	0.0671	0	0	0	0	0	0	0	0	0	0	0	0
1	0.7652	0.4401	0.1149	0.0196	0	0	0	0	0	0	0	0	0	0	0
1.25	0.6459	0.5106	0.1711	0.0369	0	0	0	0	0	0	0	0	0	0	0
1.5	0.5118	0.5579	0.2321	0.061	0.0118	0	0	0	0	0	0	0	0	0	0
1.75	0.369	0.5802	0.294	0.0919	0.0209	0	0	0	0	0	0	0	0	0	0
2	0.2239	0.5767	0.3528	0.1289	0.034	0	0	0	0	0	0	0	0	0	0
2.25	0.0827	0.5484	0.4047	0.1711	0.0515	0.0121	0	0	0	0	0	0	0	0	0
2.4	0.0025	0.5202	0.431	0.1981	0.0643	0.0162	0	0	0	0	0	0	0	0	0
2.5	-0.0484	0.4971	0.4461	0.2166	0.0738	0.0195	0	0	0	0	0	0	0	0	
2.75	-0.1641	0.426	0.4739	0.2634	0.1007	0.0297	0	0	0	0	0	0	0	0	
3	-0.2601	0.3391	0.4861	0.3091	0.132	0.043	0.0114	0	0	0	0	0	0	0	0
3.5	-0.3801	0.1374	0.4586	0.3868	0.2044	0.0804	0.0254	0	0	0	0	0	0	0	0
4	-0.3971	-0.066	0.3641	0.4302	0.2811	0.1321	0.0491	0.0152	0	0	0	0	0	0	0
4.5	-0.3205	-0.2311	0.2178	0.4247	0.3484	0.1947	0.0843	0.03	0.0091	0	0	0	0	0	0
4.75	-0.2551	-0.2892	0.1334	0.4015	0.3738	0.228	0.1063	0.0405	0.0131	0	0	0	0	0	0
5	-0.1776	-0.3276	0.0466	0.3648	0.3912	0.2611	0.131	0.0534	0.0184	0	0	0	0	0	0
5.5	-0.0068	-0.3414	-0.1173	0.2561	0.3967	0.3209	0.1868	0.0866	0.0337	0.0113	0	0	0	0	0
6	0.1506	-0.2767	-0.2429	0.1148	0.3576	0.3621	0.2458	0.1296	0.0565	0.0212	0	0	0	0	0
6.5	0.2601	-0.1538	-0.3074	-0.0353	0.2748	0.3736	0.2999	0.1801	0.088	0.0366	0.0133	0	0	0	0
7	0.3001	-0.0047	-0.3014	-0.1676	0.1578	0.3479	0.3392	0.2336	0.128	0.0589	0.0235	0	0	0	0
7.5	0.2663	0.1352	-0.2303	-0.2581	0.0238	0.2835	0.3541	0.2832	0.1744	0.0889	0.039	0.0151	0	0	0
8	0.1717	0.2346	-0.113	-0.2911	-0.1054	0.1858	0.3376	0.3206	0.2235	0.1263	0.0608	0.0256	0.0096	0	0
8.5	0.0419	0.2731	0.0223	-0.2626	-0.2077	0.0671	0.2867	0.3376	0.2694	0.1694	0.0894	0.041	0.0167	0	0
9	-0.0903	0.2453	0.1448	-0.1809	-0.2655	-0.055	0.2043	0.3275	0.3051	0.2149	0.1247	0.0622	0.0274	0.0108	0
9.5	-0.1939	0.1613	0.2279	-0.0653	-0.2691	-0.1613	0.0993	0.2868	0.3233	0.2577	0.165	0.0897	0.0427	0.0182	0
10	-0.2459	0.0435	0.2546	0.0584	-0.2196	-0.2341	-0.0145	0.2167	0.3179	0.2919	0.2075	0.1231	0.0634	0.029	0.012
10.5	-0.2366	-0.0789	0.2216	0.1633	-0.1283	-0.2611	-0.1203	0.1236	0.2851	0.3108	0.2477	0.1611	0.0898	0.0441	0.0195
11	-0.1712	-0.1768	0.139	0.2273	-0.015	-0.2383	-0.2016	0.0184	0.225	0.3089	0.2804	0.201	0.1216	0.0643	0.0304
11.5	-0.0677	-0.2284	0.0279	0.2381	0.0963	-0.1711	-0.2451	-0.0846	0.1421	0.2823	0.2998	0.239	0.1575	0.0897	0.0454
12	0.0477	-0.2234	-0.0849	0.1951	0.1825	-0.0735	-0.2437	-0.1703	0.0451	0.2304	0.3005	0.2704	0.1953	0.1201	0.065
12.5	0.1469	-0.1655	-0.1734	0.11	0.2262	0.0347	-0.1984	-0.2252	-0.0538	0.1563	0.2789	0.2899	0.2314	0.1543	0.0896