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Communication System I

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Chapter 7.

FREQUENCY DIVISION MULTIPLEXING.

7.1 Principle of frequency division multiplexing (FDM)

Multiplexing is a technique for combining a number of independent message signals into a composite signal suitable for transmission over a common communication channel.

The multiplexing process recommends that the signals are kept apart such that they donot interfere with each other and hence can easily be separated at the receiver end. The technique of separating the signal can be classified into,

i) Time division Multiplexing
ii) Wavelength division Multiplexing
iii) Frequency division Multiplexing.

Of the three techniques mentioned above we will be studying about frequency division multiplexing.

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Frequency Division Multiplexing (FDM)

FDM is a technique where a number of independent messages are combined by assigning a unique frequency band to each message such that these messages are donot overlap each other. The composite message is then sent over a common channel. So, FDM is basically implemented on transmitter side.

In FDM, thus, the available channel bandwidth is divided into a number of non-overlapping frequency slots and each message signal is assigned any particular slot of frequency within the passband of channel.

Examples of FDM are radio and television broadcasting in which multiple radio signals at different frequencies pass through the air at the same time. FDM is also used by telephone systems to transmit multiple telephone calls.

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A simple FDM process can be shown as,

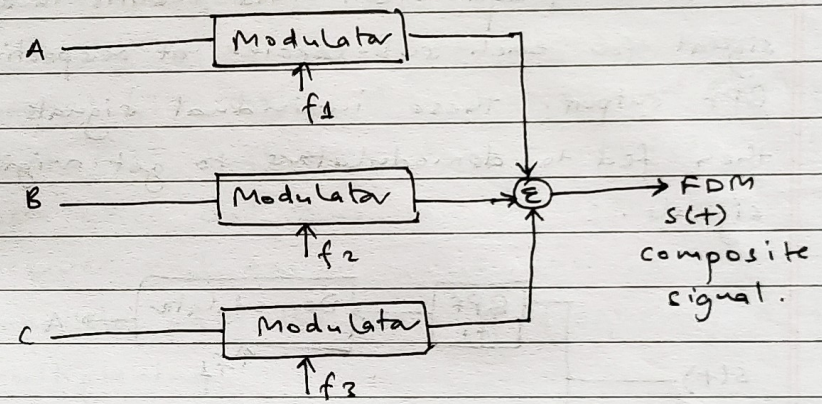


fig. Frequency division multiplexing.

The composite signal consists of different message signals that can be clearly identified in frequency domain but the multiplexed signal has no resemblance to any of its constituent in time domain.

This composite or multiplexed signal can then be transmitted as it is or may be used to modulate another higher frequency carrier before transmission.

At the receiver end, the multiplexed signal is passed through bandpass filters tuned at sub-carrier frequencies. This results in separate signal for each sub-carrier at respective BPF output. These individual signals are then fed to demodulators to get original signals.

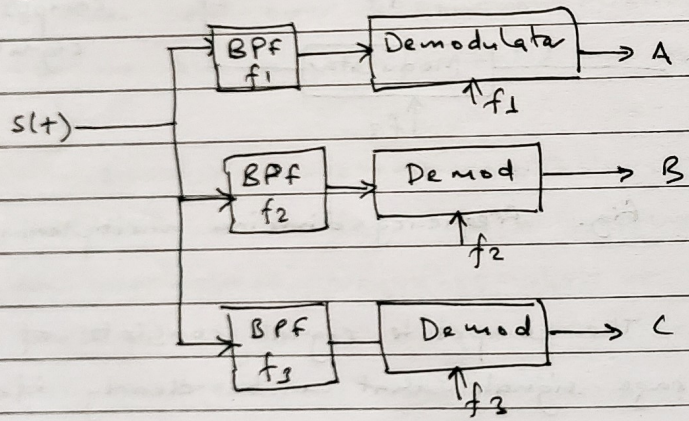


fig. Frequency division de-multiplexing.

(#) FDM in telephony :

Voice frequencies transmitted over telephone systems range from 300 to 3400 Hz. To transmit a number of these voice signals over the same channel (i.e. cable), the signals must be kept apart such that they donot interfere with each other and thus can be separated at the receiver end easily. This can be made possible with the help of frequency division multiplexing.

Now, an audio voice signal is band-limited to 300-3400 Hz i.e. 3100 Hz bandwidth. Also a coaxial cable can provide a bandwidth of 20 MHz. So, the consultative committee for international telephone & telegraphy, (CCITT) and federal communications commission (FCC) [in US & Japan] proposed and set a frequency slot of bandwidth 4 KHz, such that to 3100 Hz audio bandwidth, a guard band of 900 Hz was established.

So, with channel capacity 20 MHz, and telephone channel bandwidth 4 KHz, the total number of telephone channels allocated in the channel medium is,

$$\frac{20\ MHz}{4\ KHz} = \frac{20 \times 10^6}{4 \times 10^3} = 5 \times 10^3 \text{ telephone channels}$$

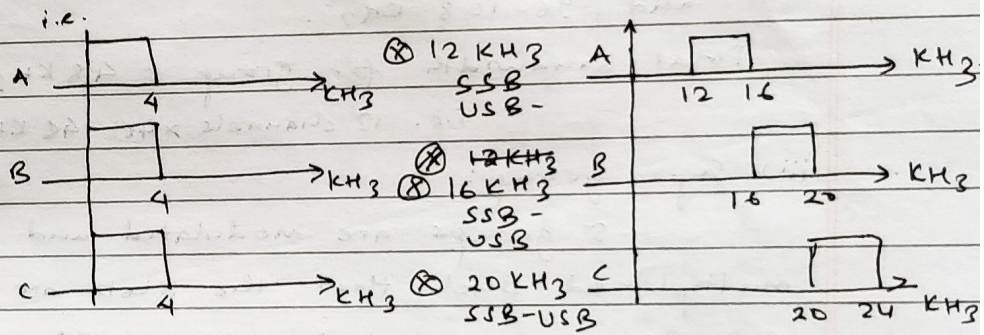
Now, since all the signals are bandlimited to 300-3400 Hz, if we transmit the all the signals as it is then they will ~~not~~ overlap. Thus, these individual signals are first modulated to different & distinct frequencies. For bandwidth efficiency, SSB-USB modulation is preferred.

Again to fully utilize the channel medium, 5000 different telephone channels need to be modulated i.e. need for 5000 single sideband modulators are evident.

To decrease the no. of such SSBs, filters etc, hierarchical system was developed.

FDM Hierarchy.

i) Pre-group: In pre-group, three telephone channels are multiplexed at 12 KHz, 16 KHz & 20 KHz ~~SSB~~ using SSB-USB



When A, B and C are multiplexed the composite signal is a pre group.

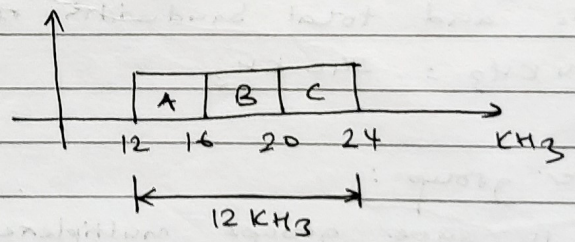


Fig. A pre group.

Thus the pre-group has a bandwidth of 12 KHz

ii) Group:

In a group channel, four pre-groups are SSB-~~USB~~ modulated at 84 KHz, 96 KHz, 108 KHz and 120 KHz and are multiplexed. ~~to give~~ Thus, the group slots are, 60-72 KHz, 72-84 KHz, 84-96 KHz and 96-108 KHz.

Total bandwidth for group = 48 KHz.

i.e. 12 channels x 4K = 48 KHz

iii) Super group:

5 groups are modulated and multiplexed such that the slots are at 312-360 KHz, 360-408 KHz, 408-456 KHz, 456-504 KHz & 504-552 KHz.

A super group thus has, 3x4x5 = 60 channels and total bandwidth of

60x4 KHz = 240 KHz

iv) Master group:

10 super groups multiplexed to give 600 channels with bandwidth of 2.52 MHz. Here the slots are spaced between 564 - ~~3084~~ 3084 KHz.

v) Jumbo group:

6 master groups multiplexed.

BW = 16.984 MHz.

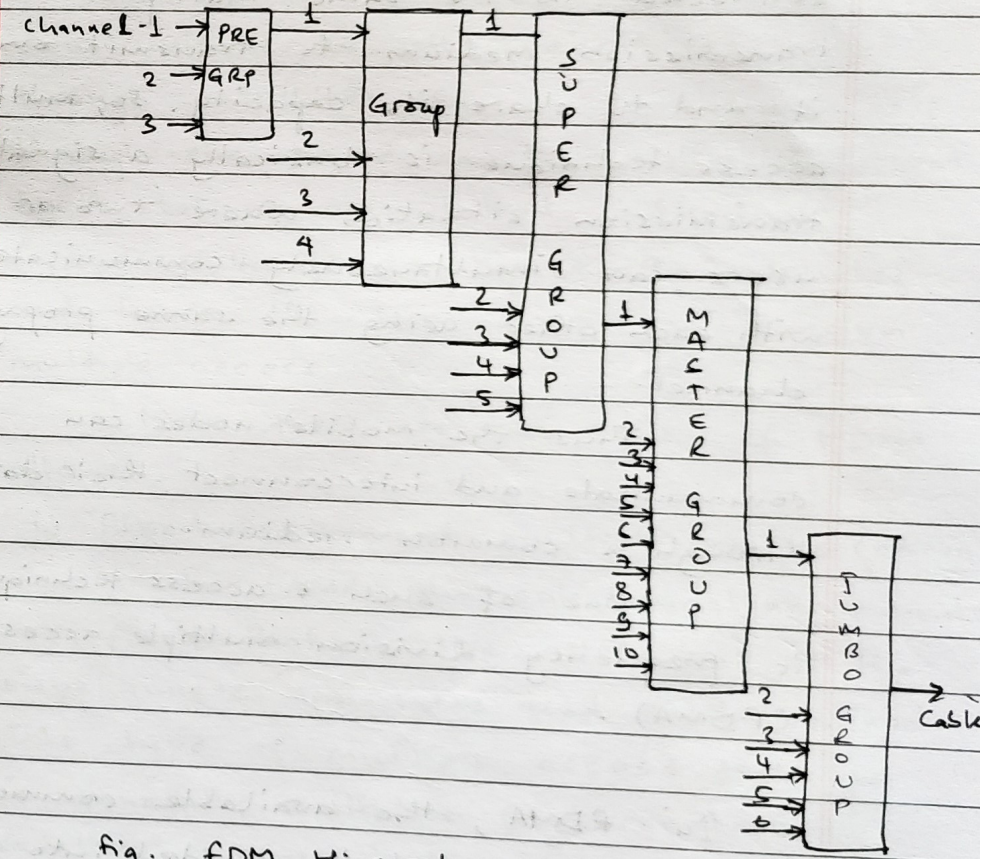


fig. FDM Hierarchy

7.2 Frequency division multiple access (FDMA) system

Multiple access method allows several users/subscribers or terminals to be connected to the same multipoint transmission medium to transmit over it and to share its capacity. So, multiple access technique is basically a signal transmission situation where two or more users can simultaneously communicate with each other using the same propagation channel.

Thus the mobile nodes can communicate and interconnect their data through a common medium.

One of such * access techniques is frequency division multiple access (FDMA).

In FDMA, the available common medium or channel is divided into separate bands and hence smaller channels are made. One user is allowed to use any particular frequency band for infinite amount of time for wireless communication.

In terms of satellite communication, the users are the earth stations that communicate to other earth stations through satellites. So, the to communicate through the same satellite, the different earth stations are allotted individual frequency bands to access the satellites and hence the term frequency division multiple access.

Now, there are two types of FDMA allowed,

i) fixed assignment multiple access (FAMA)

In FAMA, the subchannel assignments are fixed that is the allotment of the subchannels are same and predetermined. This type of multiple access technique is generally suitable for broadcast satellite communication where the data needs to be shared all the time.

ii) Demand assigned multiple access (DAMA).

As the name implies, the sub channel allotment depends and changes with demand i.e. the allotment changes with the user's demand.

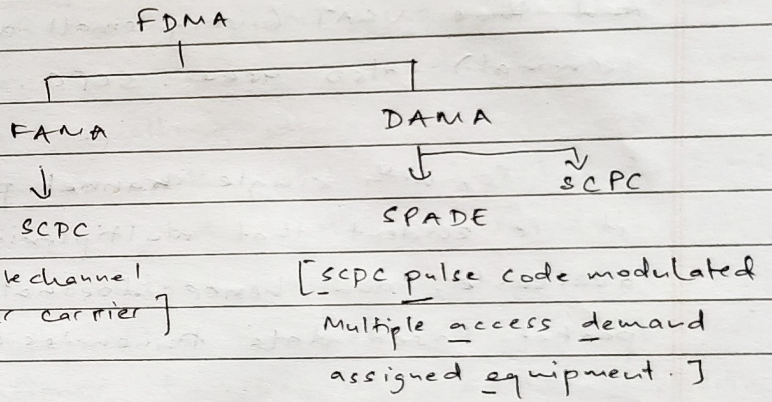
So, when any channel is not in use, the channel is returned to the central pool for reassignment to other users.

This type is generally used for point to point communication.

So, if the number of users is less than or equal to the total number of available channels then FAMA can be applicable and suitable but still the channels can stay idle if no communication occurs.

But if the no. of users is more than the available channels then it is imperative that DAMA is applied.

A DAMA is thus flexible in the sense that channel may be allowed according to the change in demand.



(#) SCPC [Single channel per carrier]

An SCPC scheme or system requires that any accessible bandwidth is dedicated to a single source. For remote regions where there are not many stations, fixed assigned SCPC can be used. But for the purpose of security or defense application, on demand basis, a single transponder channel is provided to a single carrier.

so, SCPC can be considered as a FAMA or DAMA as per the ~~req~~ requisition.

Satellite radio which needs to broadcast continuously uses SCPC system. ~~And then~~ VSAT (very small aperture terminal) also uses SCPC.

So, with single channel per carrier, it is evident that multiplexing is not available, and hence doesnot support packet based data transmission.

SPADE

[SCPC pulse code modulated multiple access demand assigned equipment.

In SPADE system, a number of earth stations are connected ~~pre~~ permanently to the satellite through common signalling channel (CSC).

Any of such stations have ability to generate any one carrier frequency out of the band allotted. A frequency pair is then selected in random manner between two stations that needs to communicate ~~the~~ through the central pool of CSC.

Basically there is a pool of 800 channels available to ground stations having common signalling channel.

So, if earth station 'A' wishes to establish link between station 'B', 'A' selects free channels randomly and through CSC, send information on selected channel. When 'B' confirms it, the link is established.

During the 'link established' period, no other stations are allowed to use that particular frequency.

(#) Filter and oscillator requirement in FDM.

In FDM, it can be noted that every individual signal with similar frequency are trasferred to unique frequency band. Thus it is necessary that these transferred signals are separated by some margin such that interferences or crosstalks do not occur.

In FDM based telephony we can see that there is a guard band of 950 Hz. Thus it is imperative that the oscillators used to generate different carrier frequencies are strictly accurate. Hence highly stable quartz controlled oscillators are implemented.

Similarly filters should be tuned to their respective frequency since any instability in tuning and drift in centre frequency can result in overlapping of adjacent signals and hence crosstalks.