4.2.3 MSK Transmitter

- Fig 4.4 shows the MSK transmitter. For two input sinusoidal waves, one is carrier signal $\cos(2\pi f_c t)$ and another one is $\cos[2\pi t / 4T_b]$ are mixed (multiplied) as,

$$\cos(2\pi f_c t)\cos\left(\frac{2\pi f_b t}{4}\right) = \frac{1}{2}\cos 2\pi\left[f_c + \frac{f_b}{4}\right]t + \frac{1}{2}\cos 2\pi\left[f_c - \frac{f_b}{4}\right] \quad \dots (1)$$

- This produces two phase-coherent sinusoidal waves at frequencies f_1 and f_2 which are related to the carrier frequency at $f_c+\frac{1}{4\,T_b}$ and $f_c-\frac{1}{4\,T_b}$.

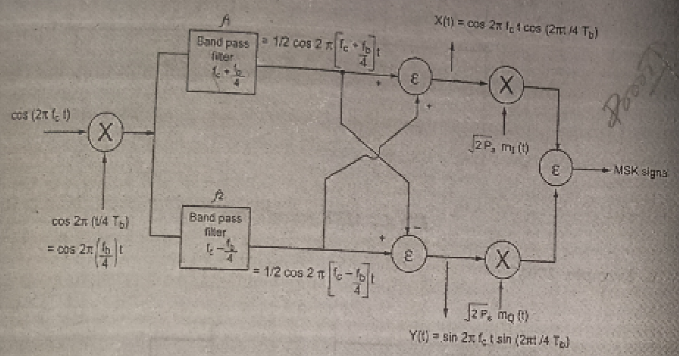

Fig 4.4 MSK transmitter

- These two FSK signals are separated from each other by two ***narrow band pass filters centered*** at f_1 and f_2 respectively.
- The *outputs* of band pass filters are then added and subtracted to form the ***in-phase*** and ***quadrature carrier*** components $X(t)$ and $Y(t)$ respectively.

$$X(t) = \frac{1}{2}\cos 2\pi\left[f_c+\frac{f_b}{4}\right]t+\frac{1}{2}\cos 2\pi\left[f_c-\frac{f_b}{4}\right] \qquad \ldots (2a)$$

$$Y(t) = \frac{1}{2}\cos 2\pi\left[f_c-\frac{f_b}{4}\right]t-\frac{1}{2}\cos 2\pi\left[f_c+\frac{f_b}{4}\right] \qquad \ldots (2b)$$

- Finally, $X(t)$ and $Y(t)$ are multiplied with odd and even bits of the binary input waves. $X(t)$ is multiplied by $\sqrt{2P_s}\ m_I(t)$ and $Y(t)$ is multiplied by $\sqrt{2P_s}\ m_Q(t)$, both of which have a bit rate equal to $\frac{1}{2}T_b$.

- The ***outputs*** of the multipliers are then added in order to give MSK modulated signal $S(t)$. So, the MSK waveform is obtained with a continuous phase throughout the time interval as well as at data transitions.

4.2.4 MSK Receiver

- The MSK signal can be detected either ***non-coherently*** (or) ***coherently.*** The received noisy MSK signal $S(t)$ is correlated with the locally generated replicas of the coherent reference signals $X(t)$ and $Y(t)$.

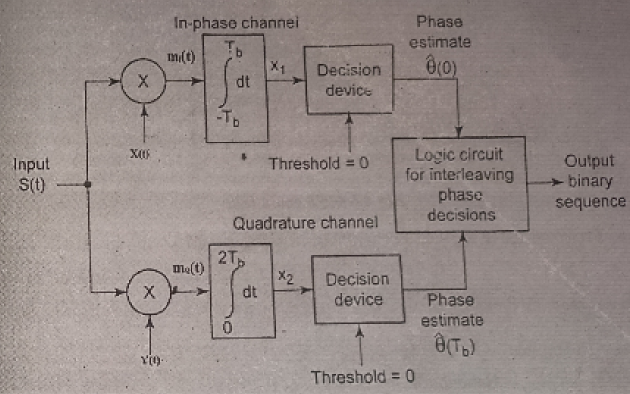

Fig 4.5 Coherent MSK receiver

- The ***outputs*** of the multipliers are integrated over the period of $2T_b$. The quadrature channel is delayed by T_b seconds mainly with respect to in-phase channel.
- The ***resulting*** in-phase and quadrature channel correlator outputs, X_1 and X_2, are each compared with a threshold of zero, and estimates the phase $\hat{\theta}(0)$ and $\hat{\theta}(T_b)$.

- Finally, these phase decisions are interleaved so as to reconstruct the original input binary sequence with the minimum average probability of symbol error in an AWGN channel.

4.2.5 Bandwidth of MSK

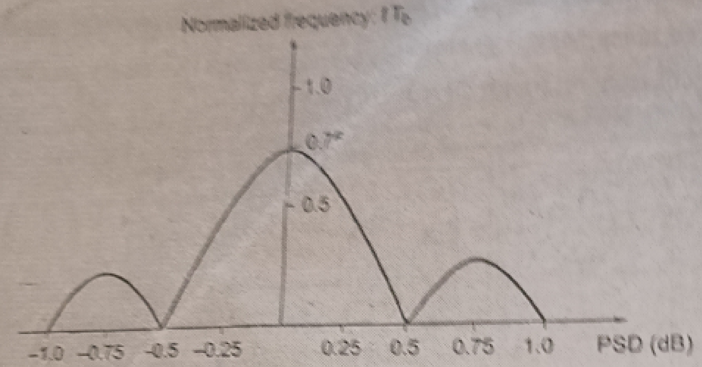

Fig 4.6 MSK main lobe

- From the above Fig 4.6, the main lobe in MSK is $\pm$ 0.75.

$$f T_b = \pm 0.75 \qquad \left[\because f_b = \frac{1}{T_b}\right]$$

$$f = \pm 0.75 f_b$$

$$\text{Bandwidth} = 0.75 f_b - (-0.75 f_b)$$

$$\boxed{BW = 1.5 f_b}$$

Thus, the BW of MSK is higher than that of QPSK

4.2.6 Advantages and Disadvantages of MSK

☑ **Advantages**

The *advantages* of MSK are:

(i) *Constant envelope,*

(ii) *High spectral efficiency,*

- *It is simply defined as, "the device which equalizes the dispersive effect of a channel". Equalizers are widely used in TDMA systems.*

6.2.2 Adaptive Equalization (or) Adaptive Equalizer

Definition for Adaptive Equalization

In a mobile cellular environment, the characteristics of the wireless dispersive fading channel will change randomly with time. In order for an equalizer to effectively combat ISI, the equalizer coefficients will change according to the channel status so as to ***track*** *the time varying characteristics of the mobile channel. This equalizer is called as* ***adaptive equalizer*** *and the equalization process is known as an* ***adaptive equalization*** *as it* ***adapts*** *to the* ***channel variations.***

6.2.3 Operating Modes of Adaptive Equalizer

The two general operating modes of adaptive equalizers: ***training*** and ***tracking.***

(i) Training

- *First, a known fixed –* ***length training sequence*** *is sent by the transmitter, then the receiver's equalizer may adapt to a proper setting of* ***minimum Bit Error Rate (BER)*** *detection, where the training sequence is a* ***pseudorandom binary signal*** *(or) a* ***fixed and prescribed*** *bit pattern.*
- *Immediately following this training sequence, the user data is sent, and the adaptive equalizer at the receiver utilizes a* ***recursive algorithm*** *to evaluate the channel and estimate filter coefficients to compensate the distortion created by a multipath in the channel.*

(ii) Tracking

- *As user data are received, the adaptive algorithm of the equalizer tracks the changing channel and as a consequence, the adaptive equalizer is continually changing its filter characteristics over time.*

6.2.4 Operating Principle

- Fig 6.2 shows the block diagram of adaptive equalizer at the receiver. If $x(t)$ is the original information signal, and $f(t)$ is the combined complex, base band impulse response of the transmitter, channel, and the RF/IF sections of the receiver.

- The signal received by the equalizer may be expressed as,

$$y(t) = x(t) \otimes f^*(t) + n_b(t) \qquad \dots (1)$$

where, $f^*(t)$ – Complex conjugate of $f(t)$,

$n_b(t)$ – Baseband noise at the input of the equalizer, and

$\otimes$ – Convolution operation.

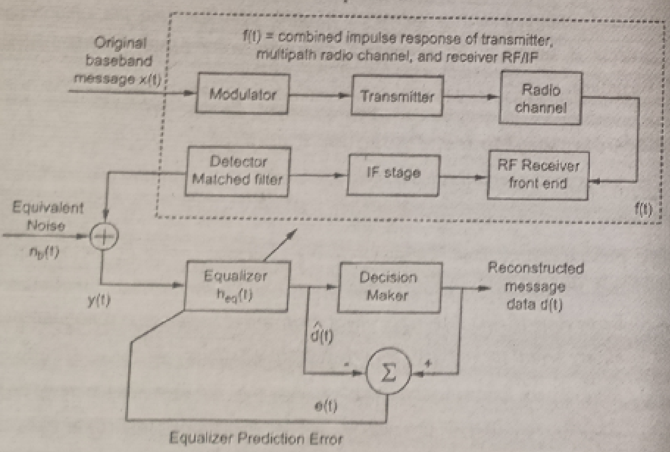

Fig 6.2 Block diagram of a simplified communications system using an adaptive equalizer at the receiver

- If the impulse response of the equalizer is $h_{eq}(t)$, then the output of the equalizer is expressed as,

$$\hat{d}(t) = x(t) \otimes f^*(t) \otimes h_{eq}(t) + n_b(t) \otimes h_{eq}(t) \qquad \dots (2)$$

$$= x(t) \otimes g(t) + n_b(t) \otimes h_{eq}(t)$$

where, $g(t)$ is the combined impulse response of the transmitter, channel, RF/IF sections of the receiver, and the equalizer at the receiver.

- The complex baseband impulse response of a transversal filter equalizer is given as,

$$h_{eq}(t) = \sum_n c_n \delta(t - nT) \qquad \dots (3)$$

where, c_n – Complex filter coefficients of the equalizers.

- The desired output of the equalizer is $x(t)$ which is the original source data. Assume that $n_b(t) = 0$, then to get $\hat{d}(t) = x(t)$ in equation (2), $g(t)$ must be equal to,

$$g(t) = f^*(t) \otimes h_{eq}(t) = \delta(t) \qquad \dots (4)$$

- The goal of equalization is to satisfy the equation (4). So that the combination o the transmitter, channel and receiver appear to be an all-pass channel. I frequency domain, the equation(4) can be expressed as,

$$H_{eq}(f)\, F^*(-f) = 1 \qquad \dots (5)$$

where, $H_{eq}(f)$ and $F(f)$ are Fourier transforms of $h_{eq}(t)$ and $f(t)$, respectively

- Equation (5) indicates that an equalizer is actually an inverse filter of the chann If the channel is frequency selective, the equalizer enhances the frequen components with small amplitudes and attenuates the strong frequencies in received frequency spectrum in order to provide flat, composite, recei frequency response and linear phase response.

☒ **Disadvantages:**

...vantages of selection diversity are,

(i) ...not an optimal diversity technique because it does not use all of the possible branches simultaneously.

(ii) *Selection diversity wastes signal energy by discarding (N_R-1) copies of the received signal.*

6.4.4 Feedback or Scanning Diversity

- *Scanning diversity is very similar tofff selection diversity except that instead of always using the best of M signals and are scanned in a fixed sequence until one with SNR is found to be above a predetermined threshold.*

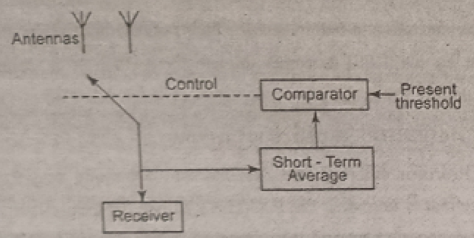

Fig 6.13 Block diagram of scanning diversity

- This signal is then received until it falls below threshold and the scanning process is again initiated.

☑ **Advantages**

(i) It is very simple to implement.

(ii) Only one receiver is required.

6.4.5 Diversity Combining Techniques (or) Combining Diversity

- The drawbacks of selection diversity are overcome by combining diversity which exploits all available signal copies. Each signal copy is multiplied by a complex weight, and then added up and it is expressed as,

$$\boxed{\text{Complex weight } (\omega_n^*) = \text{Phase correction} + \text{Real weight of the amplitude}}$$

- Phase correction causes the signal amplitudes to add up, otherwise noise is added incoherently, so that noise power add up. For amplitude weighting, two methods are used:

(i) Maximal Ratio Combining (MRC)

Weights all received signal copies based on their amplitude.

(ii) Equal Gain Combining (EGC)

Signals are not weighted, but undergo a phase correction to make all amplitude weights are same.

(1) Maximal Ratio Combining (MRC)

Principle:

Combining all the signals in a co-phased and weighted manner so as to have the highest achievable SNR at the receiver at all the times.

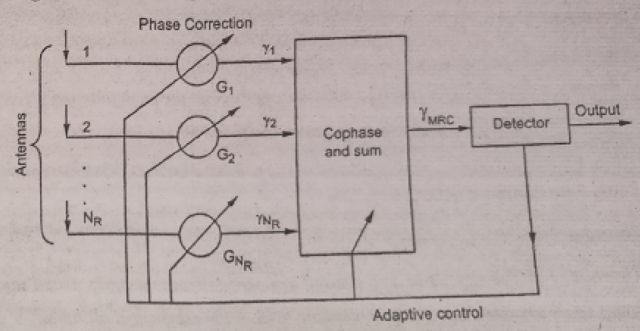

Fig 6.14 Block diagram of maximal ratio combiner

- In this method, the signals from all of the N_R branches are weighted according to their individual ***signal voltage to noise power*** ratios and then summed.

- Fig 6.14 shows a block diagram of MRC technique. Here, the individual signals must be co-phased before being summed which generally requires an individual receiver and phasing circuit for each antenna element.
- Maximal ratio combining produces an output SNR which is equal to the sum of the individual SNRs that is, *the output SNR of the diversity combiner is the sum of the branch SNRs:*

$$\gamma_{MRC} = \sum_{n=1}^{N_R} \gamma_n$$

☑ **Advantages**

The advantages of MRC are,

(i) It is producing an output with an acceptable SNR even when none of the individual signals are themselves acceptable.

(ii) It gives the ***best statistical reduction*** *of fading of any known linear diversity combines.*

☒ **Drawbacks**

The drawbacks of MRC are,

(i) It requires an individual receiver and phasing circuits for each antenna elements which results in an increasing complexity of the circuit.

(ii) High cost.

(2) Equal Gain Combining (EGC) Diversity

Principle:

Combining all the signals in a co-phased manner with unity weights for all signal levels so as to have the highest achievable SNR at the receiver at all times.

- In some cases, it is not convenient to provide for the variable weighting capability which is required for true maximal ratio combining. At that time, we are going for Equal Gain Combining (EGC) diversity technique.

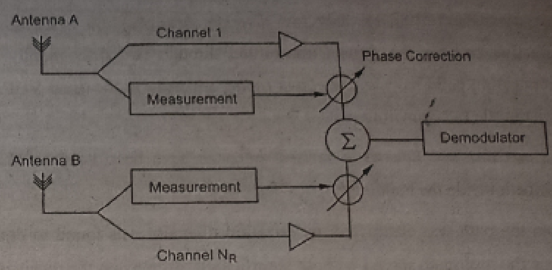

Fig 6.15 Simple block diagram of EGC

- It is similar to maximal-ratio combining, except that the weighting circuits are omitted. In this method, the ***branch weights are all set to unity,*** but the signals from each branch are co-phased to provide an ***equal gain combining diversity.***
- This allows the receiver to exploit the signals that are ***simultaneously*** received on each branch.
- The possibility of producing an acceptable signal from a number of unacceptable inputs are still retained, and performance is only marginally ***inferior*** to maximal ratio combining and ***superior*** to selection diversity

6.5 POLARIZATION DIVERSITY

6.5.1 Introduction

Definition of Polarization Diversity

Multiple versions of a signal are transmitted and received via antennas w different polarization. The transmitted signal with ***horizontal*** *or vert polarization is received by an antenna with two elements and a dive combining technique is applied on the receiver side.*

- In this kind of diversity, one element is used for horizontal polarization an other is used for vertical polarization.

10. *Name the different micro diversity methods.*

(OR)

List the different types of diversity schemes.

[APR/MAY-2014 & APR/MAY -2018]

The five most common micro diversity methods used are,

(i) Spatial Diversity- Several antenna elements separated in space.

(ii) Time Diversity – Transmission of the transmit signal at different times.

(iii) Frequency Diversity – Transmission of the signal on different frequencies.

(iv) Polarization Diversity – Multiple antennas with different polarizations.

22. ***What is the difference between frequency and time diversity? Give example for each type of diversity. [NOV/DEC-2022]***

Frequency diversity and time diversity are two vital types of diversities to diminish the fading of the communication signal to enhance the signal quality between sender and receiver.

Frequency diversity means changing the frequency of the same signal or increasing the number of frequency carriers.

Example: OFDM

On the other hand, time diversity means transmitting the same signal at a different time interval to avoid fading and disturbance in the signal.

Example: Spread spectrum CDMA.

5. ***What is MSK?*** ***[NOV/DEC -2016]***

Minimum Shift Keying (MSK) is a special type of binary Continuous Phase Frequency Shift Keying (CPFSK) ,where in the peak frequency deviation is equal to 1/4 the bit rate and modulation index $h = 1/2$. This leads to the minimum frequency spacing that makes the two FSK signals orthogonal to each other.

10. *Define GMSK.*

(OR)

Why GMSK is used in cellular communication? ***[APR/MAY-2022]***

Gaussian Minimum Shift Keying (GMSK) is a simple binary Continuous Phase Frequency Shift Keying (CPFSK) modulation scheme with modulation index $h = 0.5$ which may be viewed as a derivative of MSK.

The word Gaussian refers to the shape of a filter that is used before the modulator in the transmitter to reduce the sidelobe levels of the transmitted signal. GMSK uses less bandwidth than conventional FSK.

4.3.2 GMSK Transmitter

- Gaussian pulse-shaping filter is particularly effective when used in ***conjunction*** with ***Minimum Shift Keying (MSK)*** modulation, or other modulations which are well suited for ***power efficient non-linear amplifiers.***
- The simplest way to generate a GMSK, by pass a NRZ message bit stream through a Gaussian baseband filter having an impulse response given in equation(1).

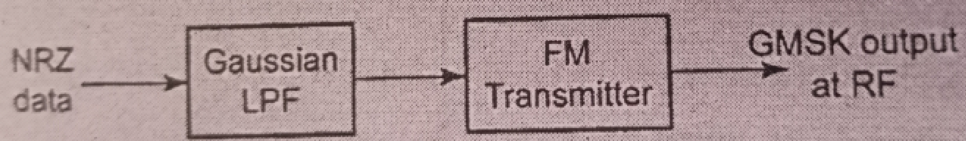

Fig 4.7 Block diagram of a GMSK transmitter using direct FM generation