**Question 1:**

(X(us)/500)×2π

**Question 2: Why must a product detector be used to recover the message instead of an envelope deetector?**

A product detector must be used to recover the message instead of an envelope detector in the case of Double Sideband Suppressed Carrier (DSBSC) modulation. This is because the envelopes of a DSBSC signal are not the same shape as the original message. In contrast, an envelope detector can be used to recover the original message from an Amplitude Modulation (AM) signal, where the carrier makes up a significant portion of the signal's power and contains the shape of the message. However, for DSBSC, where the carrier is not transmitted, thus saving power, the envelope detector is ineffective. DSBSC signals require a product detector (also known as a synchronous detector or switching detector) for demodulation​.

**Question 3: Compare the width of the spectrum when using the Rectangular window and Hanning window for the FFT operation. Which window type would produce a thinner spectrum width?**

The Hanning window generally produces a spectrum with a narrower width. It is a type of tapered window, reduces spectral leakage. It does so by smoothly reducing the signal values to zero at the edges of the window, leading to a narrower and more concentrated spectrum. This makes it easier to distinguish between closely spaced frequency components.

**Question 5: Given the size of the recovered message’s amplitude, what is the likely phase error between the two carriers?**

The phase error between two carriers in a DSBSC (Double Sideband Suppressed Carrier) modulation system can be inferred from the amplitude of the recovered message. When adjusting the Phase Shifter module's control, if the amplitude of the recovered message is at its maximum, this suggests that the phase error between the two carriers is minimal. Conversely, if the amplitude of the recovered message is at its smallest, this indicates a significant phase error between the two carriers.

In practical terms, when the phase error is small, the two carriers are more in phase with each other, leading to a stronger recovered message. As the phase error increases, the two carriers become more out of phase, which weakens the amplitude of the recovered message. The exact relationship between the phase error and the amplitude of the recovered message can vary based on the specifics of the system and setup but generally follows this principle.

**Question 6: Given the size of the recovered message’s new amplitude, what is the likely phase error between the two carriers?**

When the new amplitude of the recovered message is at its smallest, this indicates that there is a significant phase error between the two carriers. In the experimental procedure, this is observed by adjusting the Phase Adjust control of the Phase Shifter module and monitoring the effect on the recovered message. The smallest amplitude of the recovered message signifies that the phase difference between the two carriers is at its maximum. Under such conditions, the amplitude of the recovered message is reduced, indicating a substantial lack of synchronization between the carriers

**Question 7: How does the recovered speech sound like when you vary the VCO modules Frequency Adjust control left and right?**

When you vary the VCO module's Frequency Adjust control left and right, it affects the synchronization of the local carrier with the transmitted speech signal. As a result, the recovered speech will likely exhibit variations in pitch and clarity. Adjusting the Frequency Adjust control changes the frequency of the local oscillator, which in turn affects how well it aligns with the carrier frequency of the transmitted signal. When the frequencies are not properly synchronized, it can lead to distortions in the recovered speech, making it sound unnatural or altered in pitch​.

**Question 8: Which of these noise sources causes the worst corruption to the transmitted signal?**

Typically, in communication systems, the higher the noise level relative to the signal, the worse the corruption of the transmitted signal.

**Question 10: How does the recovered speech sound like when you vary the VCO modules Frequency Adjust control left and right, assuming a noise source of -20dB?**

When varying the VCO (Voltage Controlled Oscillator) module's Frequency Adjust control left and right, assuming a noise source of -20dB, the recovered speech will likely exhibit changes in pitch and clarity. The -20dB noise level, which is relatively low (the noise is about one-tenth the size of the signal), means that the primary factor affecting the quality of the recovered speech will be the frequency synchronization between the VCO module and the transmitted signal.

Adjusting the Frequency Adjust control alters the frequency of the local oscillator. If the frequency of the VCO does not closely match the carrier frequency of the transmitted signal, it can result in distortions in the recovered speech. These distortions may manifest as variations in pitch, speed, or clarity of the speech. The impact of the -20dB noise on this process is relatively minor, so the primary factor in the quality of the recovered speech in this scenario is the accuracy of the frequency adjustment of the VCO module​.

**Question 11: What is the VCO module’s rest frequency? Explain how you measure it.**

The rest frequency of the VCO (Voltage Controlled Oscillator) module can be measured using the following procedure:

1. Set up the VCO module by turning its Gain control to about two-thirds of its travel (approximately the position of number 2 on a clock face).
2. Adjust the VCO module’s Frequency Adjust control to about the middle of its travel.
3. Set the VCO module’s Range control to the LO position.
4. Connect the setup as shown in the experiment's Figure 20.
5. Set the oscilloscope's Timebase control to the 20 µs/div position.
6. Adjust the VCO module’s Frequency Adjust control so that one cycle of its output is exactly 5 divisions on the oscilloscope.

By following these steps, the VCO module’s rest frequency is determined by observing the output wave on the oscilloscope. The rest frequency corresponds to the frequency at which one complete cycle of the output wave spans exactly 5 divisions on the oscilloscope's display when the Frequency Adjust control is set to the middle position​​.

**Question 12: How many sinewaves does the VCO module produce?**

n FM signal generation, the VCO's output can vary in frequency depending on the modulating signal. The number of different sinewaves it produces would depend on the nature of the input signal being modulated. If the input is a speech signal, for instance, the VCO might produce a range of sinewaves corresponding to the varying frequencies present in the speech​​.

**Question 13: Why do the sinewaves have di↵erent frequencies?**

When using a VCO in an FM system, the modulating input signal (such as speech or music) causes the VCO's output frequency to fluctuate. These fluctuations correspond to the changes in amplitude of the modulating signal. Hence, different parts of the signal that have different amplitudes will cause the VCO to produce sinewaves at different frequencies. The result is a spectrum of frequencies that directly correspond to the variations in the amplitude of the input signal​​.

**Question 14: What do the FM signal’s sinewaves tell you about the message signal, i.e. bipolar or unipolar?**

If the message signal is bipolar, it means that the signal includes both positive and negative values. In the context of FM, this would result in frequency deviations both above and below the carrier frequency, corresponding to the positive and negative amplitudes of the message signal. Thus, the FM signal's sinewaves would oscillate around the carrier frequency, indicating both upward and downward frequency shifts.

If the message signal is unipolar, it means that the signal includes only positive values (or only negative values). In this case, the frequency deviations would occur in only one direction from the carrier frequency (either above or below), corresponding to the positive (or negative) amplitudes of the message signal.

**Question 15: What happens to the VCO module’s output as you talk louder? Why?**

The output of the VCO changes in terms of its frequency deviation. The VCO's output frequency varies with the amplitude of the input message signal. When the message amplitude is higher, the VCO outputs a signal with a higher frequency compared to its rest frequency, results in a greater deviation between the frequency of the FM signal and that of the carrier.

**Question 16: What is the name of the VCO output frequency that corresponds to logical-1 in the digital data? Similarly, what is the name of the VCO output frequency that corresponds to logical-0?**

Logic 1: Mark frequency; Logic 0: Space frequency.

**Question 17: Which of the FSK signal’s two sinewaves is the filter picking up?**

A low-pass filter module is used to pick out one of the FSK signal's two sinewaves. If the filter's cut-off frequency is set below the mark frequency but above the space frequency, it will pick up the sinewave corresponding to the space frequency (logical-0). Conversely, if the cut-off frequency is set above the space frequency but below the mark frequency, it will pick up the sinewave corresponding to the mark frequency (logical-1)​​.

**Question 18: What does the filtered FSK signal look like?**

The filtered FSK (Frequency Shift Keying) signal, after being processed through the filter, will typically appear as a waveform that fluctuates between two levels, corresponding to the two frequencies of the original FSK signal (the mark and space frequencies).

**Question 19: How does the -20dB noise affect the restored digital signal?**

At -20dB, the noise level is relatively low compared to the signal strength. Therefore, the restored digital signal might still maintain a good level of clarity and integrity. However, some minor distortions or errors could be introduced, especially if the signal-to-noise ratio (SNR) is close to critical levels for the specific communication system.

**Question 20: How does the -6dB noise affect the restored digital signal?**

the presence of -6dB noise can lead to difficulties in correctly interpreting the signal, causing errors in the recovered digital data. The noise may mask some of the signal's features, making it harder for the demodulator to accurately distinguish between different states (e.g., logical-0 and logical-1 in a binary system).

The impact of -6dB noise on the restored digital signal would be more severe than lower noise levels (such as -20dB), and it can significantly impair the accuracy and reliability of digital signal restoration in communication systems​​.