Unit-3 : Microwave Measurements

1. Measurement of Impedance and Power.

A. Impedance Measurement: [can use for Case Study]

Impedance (Z) is the total opposition that a circuit offers to flow of alternating current (AC).

It consists of;

- Resistance (R): Opposition to current due to resistive elements.
- Reactance (X): Opposition due to capacitors and inductors.

At microwave frequencies, impedance becomes complex (has both magnitude and phase) and highly dependent on frequency, transmission line characteristics and load conditions.

Mathematical Representation:

$$Z = R + jX$$

where; R = Resistance
X = reactance
$j = \sqrt{-1}$

Measurement Techniques:

1. **Slotted Line Method:**

→ A slotted line is a Section of waveguide with a longitudinal slot and a movable probe.

→ The Probe Senses voltage variations along the line.

→ Voltage Standing Wave Ratio (VSWR) is calculated by measuring maximum and minimum voltages.

→ From VSWR and the location of voltage minima, reflection co-efficient and impedance are calculated.

Advantages:

→ Simple and effective

→ Useful in waveguide Systems

Limitations:

→ Manual and time-Consuming

→ Limited to Single-frequency measurements.

2. Vector Network Analyzer:

→ A Vector Network Analyzer is a precision instrument used to measure the Scattering Parameters (S-parameters) of a microwave network.

→ It measures the reflection co-efficient Γ and computes impedance as;

$$Z = Z_0 \cdot \frac{1+\Gamma}{1-\Gamma}$$

where; Z_0 = characteristic impedance (usually 50Ω)

Γ = Measured reflection co-efficient

Advantages:

→ Accurate and fast
→ Works over a wide frequency range.
→ Displays results in Smith chart format.

3. Impedance Bridges:

→ Extended versions of Wheatstone bridges are used at microwave frequencies.
→ Compare unknown impedance with a known standard.
→ Can use waveguide or coaxial line formats.

Advantages:

→ High precision
→ Suitable for laboratory-grade measurements.

4. Smith Chart:

→ A graphical tool to represent complex impedances and reflection co-efficients.
→ used for impedance matching, Analysing circuit behaviour and designing matching networks.

Features:

→ Normalized impedance Representation
→ Useful in visualizing multiple frequency points.

Signal Analyzer - Unit 3

Purpose:

→ A Signal Analyzer is designed for detailed examination of complex, modulated signals commonly used in modern communication systems.

→ It Provides measurements that go beyond simple frequency analysis, such as modulation quality and signal impairments.

Working:

→ It captures the input signal and performs advanced digital signal processing to extract parameters like phase, amplitude and timing information.

→ It can demodulate signals and measure key performance metrics such as:

Error Vector Magnitude (EVM): Quantifies modulation accuracy by measuring the difference between the ideal and actual signal constellation points.

Phase Noise: Measures short-term frequency fluctuations, important for oscillator and transmitter quality.

Adjacent Channel Power ratio (ACPR): Measures power leakage into adjacent frequency channels, critical for minimizing interference.

Types of Signal Analyzers

1. Vector Signal Analyzer (VSA):

→ Analyses both magnitude and phase of complex modulated signals.

→ Used for demodulation, constellation analysis, EVM measurements and phase noise.

→ Common in digital communication testing (eg: LTE, 5G, Wi-Fi).

2. Modulation Analyzer:

→ Focuses on measuring modulation quality parameters like EVM, ACPR and distortion.

→ Suitable for analog and digital modulated signals (QAM, PSK, FM, AM).

3. Phase Noise Analyzer:

→ Specialized in measuring phase noise and jitter of Oscillators and RF Sources.

→ Helps improve Oscillator design and clock stability.

4. Time domain Signal Analyzer:

→ Analyses transient signals, timing jitter, pulse characteristics in the time domain.

→ Useful in radar, pulsed communications and transient event analysis.

Applications:

→ Testing modulation quality (EVM, constellation accuracy)
→ Developing and optimizing communication Systems.
→ Measuring phase noise of oscillators
→ Analyzing adjacent channel interference (ACPR)
→ Analyzing radar and pulsed signals.
→ Troubleshooting signal distortion & noise.

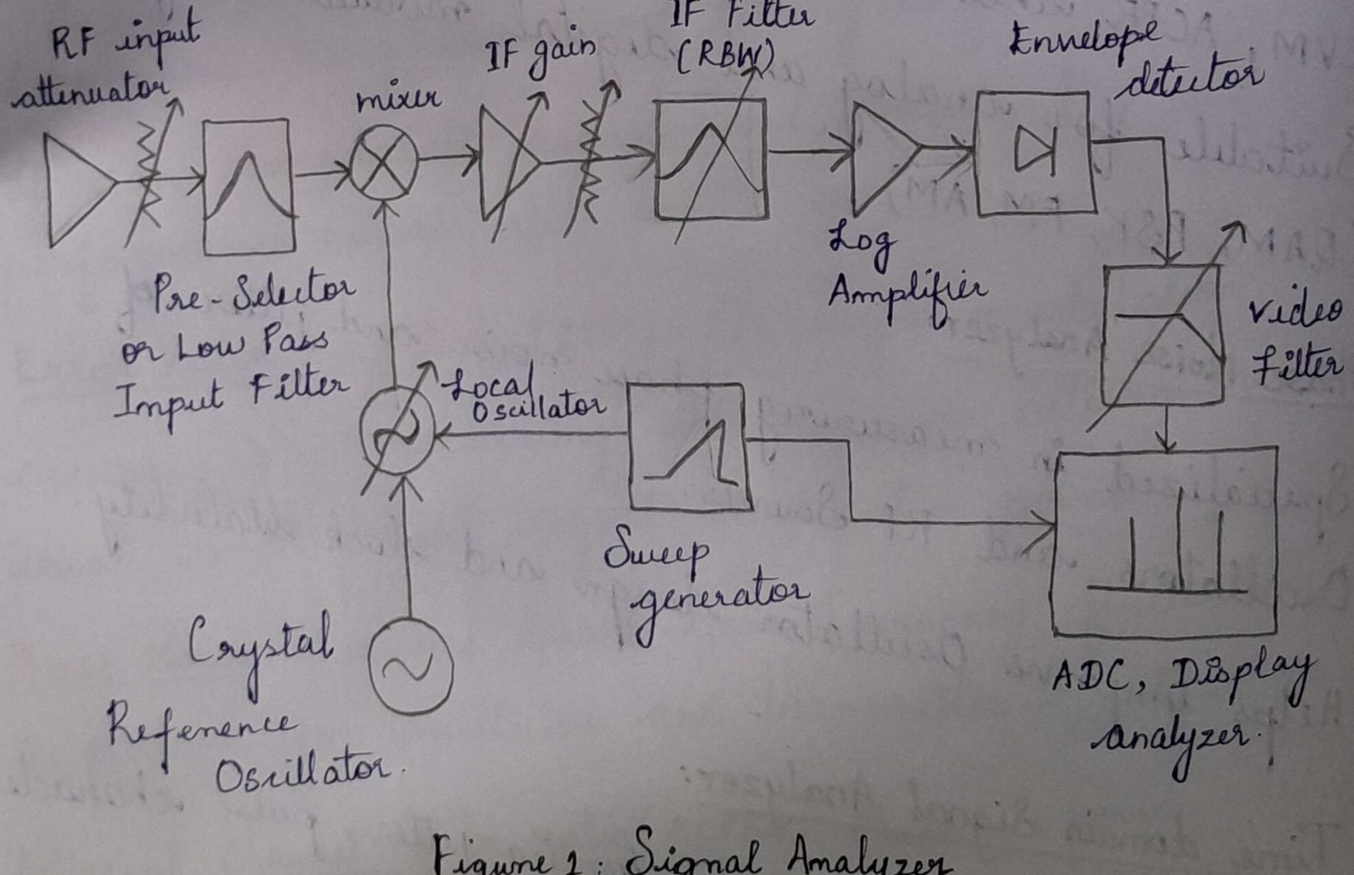

Figure 1: Signal Analyzer

Book References (Chapter - 15) - Microwave Communication

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1. Impedance Measurement - Page 707 to 710 (15.11, 15.11.1, 15.11.2)
   Fig: 15.19

2. Power Measurement - Page 695 to 699 [15.7, 15.7.1, 15.7.2, 15.7.4]
   Fig: 15.9, 15.10, 15.12

3. Frequency Measurement - Page 710 to 712 [15.12, 15.12.1, 15.12.2, 15.12.
   Fig: 15.23, 15.24

4. Attenuation Measurements - Page 700 to 702 [15.8]
   Fig: 15.14

5. Scattering Paramters - Page 724 to 726 [15.15, 15.15.1, 15.15.2]
   Fig: 15.32 (a), Fig 15.33

6. Network Analyzer - Page 693 to 695 [15.6]
   Fig: 15.5, 15.6

7. Spectrum Analyzer - Page 692 & 693 [15.5]
   Fig: 15.4

8. VSWR (voltage Standing Wave ratio) - Page 702, 704, 705 [15.9, 15.9.1, 15.9.2]
   Fig: 15.15 (a), 15.16