Some Useful Microwave Definitions

1. Some Units Definitions

dB, dBm, dBc:

For a power related parameter X,

X(dB) = 10Log (X)

For a voltage or current related parameter X,

X(dB) = 20Log (X)

For a power level X in milliwatt of a signal,

X(dBm) = 10Log (X)

The power level difference between two carriers

X(dBc) = P_1(dBm) – P_2(dBm)

2. Surface Resistance and Skin Depth

Surface resistance is defined as:

$$R_S = \sqrt{\frac{\omega\mu}{2\sigma}}$$

where ω is the angular frequency, μ permeability, and σ conductivity.

3. Skin Depth

Skin depth, characteristic depth penetration of a high frequency signal in a surface of a good conductor is defined as:

$$\delta_S = \sqrt{\frac{2}{\omega\mu\sigma}}$$

4. Characteristic Impedance Z_0

For a negligible loss transmission line, the characteristic impedance can be described as:

$$Z_0 = \sqrt{\frac{L}{C}}$$

where L and C are the unit series inductance and shunt capacitance of a transmission line.

5. Reflection Coefficient *Γ*

The reflection coefficient ***Γ*** is defined as

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

where Z_L is a load impedance.

6. Return Loss, Insertion Loss, and VSWR

$$RL = -20\log|\Gamma|,\ IL = -20\log|T|, \text{ and } VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

|Γ|	0.024	0.032	0.048	0.056	0.10	0.0178	0.200	0.316	0.330
VSWR	1.05	1.07	1.10	1.12	1.22	1.43	1.50	1.92	2.00
RL(dB)	32.3	30.0	26.4	25	20	15	14	10	9.6

7. Noise Figure

Noise figure is defined as the ratio of the input signal-to-noise ratio to the output signal-to-noise ratio.

$$NF = \frac{S_i/N_i}{S_o/N_o}$$

For a cascaded system, the total noise figure is measured as

$$NF_t = NF_1 + \frac{NF_2 - 1}{G_1}$$

where NF_1 is the first stage noise figure, G_1 the first stage gain, and NF_2 the second stage noise figure.

Noise figure in dB form:

$$NF(dB) = 10\log(NF)$$

8. Intermodulation

Two-tone method is a basic measure of a system's intermodulation behavior. As shown in **Figure 1**, the combined two signals with the equal amplitude at certain different frequencies are fed to a system such as an amplifier. Besides the amplified two tone signals, there are additional intermodulation products are generated by the system due to the non-linearity.

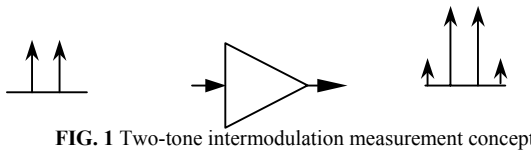

FIG. 1 Two-tone intermodulation measurement concept.

Third order intermodulation products can be defined in:

a) Third order output interception point,

$$TOIP_3(dBm) = P_0(dBm) + \frac{P_0(dBm) - P_3(dBm)}{2}$$

P_0 and P_3 are the power level of the first order and third order at the output.

b) Third Order Intermodulation in dBc Term

$$IMD_3 = P_0(dBm) - P_3(dBm)$$

9. S-Parameters Of A System Such As An Amplifier

A vector network analyzer can measure the S-parameters of a system such as an amplifier accurately with a proper calibration method such as Full-Two-Port or TRL. For a two-port network, there are four S-parameters S_{11}, S_{21}, S_{12}, and S_{22}. An example of the S-parameter in .S2P format for an amplifier is

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!ATF-34143
!S-PARAMETERS at Vds=2V  Id=20mA.  LAST UPDATED 01-29-99
# GHz s ma r 50
!Freq  MAG[S11]  ANG[S11]  MAG[S21]  ANG[S21]  MAG[S12]  ANG[S12]  MAG[S22]
ANG[S22]
0.5    0.97      -37       9.718     153       0.036     68        0.36      -38
0.8    0.91      -60       9.29      137       0.051     56        0.31      -61
1.0    0.87      -77       8.545     126       0.063     48        0.3       -78
!FREQ        Fopt          GAMMA        OPT        RN/Zo
!GHZ    dB    MAG    ANG    -
```

0.5	0.10	0.90	14	0.17
0.8	0.11	0.85	28	0.14
1.0	0.11	0.83	32	0.13