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REFLECTION MEASUREMENTS USING WEINSCHEL ENGINEERING MODEL VM-4A/HO-2/4312 SYSTEM

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ABSTRACT

The paper presents a setup of reflection measurements using Weinschel Engineering model VM-4A/HO-2/4312 system. A 40 dB directivity directional bridge, model 8721A(HP), is used in the system for reflection measurements from 10 to 110 MHz, which provides new means of precision measurement. High frequency measurements are performed by using dual directional couplers, reflectometer bridges, etc. Other precision measurement systems which use model 560 Scalar Network Analyzer (Wiltron), model 8407A Network Analyzer (HP) and model 8566A Spectrum Analyzer (HP) are also discussed.

INTRODUCTION

Measurements are at the heart of analytical design and controlled production. To enable today's systems we must make measurements that are accurate for even small standing wave ratios (SWR) and fast to accomplish. A tremendous advancement in the field of electrical and electronic measurements technology has led to the development and manufacture of the highest quality microwave components,
and precise microwave measurement and calibration instruments.

The focus of this presentation will be on reflection measurements using VM-4A/HO-2/4312 Attenuator and Signal Generator Calibrator System (Weinschel Engineering), 5600 Automated Scalar Network Analyzer System (Wiltron), 8407A Network Analyzer System (Hewlett Packard) and 8566A Spectrum Analyzer (Hewlett Packard). To measure reflected signals, a directional device is required to separate the reflected signal from the incident or test signal. The accuracy of reflection measurements is limited by both the directional device and the system in which it is used. The reflection measurements output of the above systems are in terms of return loss (RL) in decibels from which reflection coefficient is calculated:

Reflection Coefficient (ρ) = $10^{(-RL/20)}$
and Voltage Standing Wave Ratio (VSWR) = $\frac{1 + \rho}{1 - \rho} = \frac{1 + 10^{(-RL/20)}}{1 - 10^{(-RL/20)}}$

The random uncertainty of the measurements is defined as:

$\delta = \pm \frac{t}{\sqrt{n}}$ S, where t is the student's t factor based on the confidence level required (95% or 99%), n is the number of measurements and S is the standard deviation of the sample.

SYSTEMS OF MEASUREMENTS

The Weinschel Engineering model VM-4A/HO-2/4312 System, when used with a directional bridge, dual directional coupler, reflectometer bridge, etc., sets a new standard for microwave measurement of return loss. Three other precision measurement systems will also be considered here.

1. WEINSCHEL ENGINEERING MODEL VM-4A/HO-2/4312 SYSTEM:

The Weinschel Engineering model VM-4A/HO-2/4312 is a dual channel IF Vector substitution set[1] with a tracking local oscillator and a stable phase locked RF source. The system is commonly used for precise attenuation measurement based on a substitution technique where the insertion loss of an attenuator driven by a stable RF source is alternately compared to that of a reference attenuator driven by a stable IF reference source. The RF output of the attenuator being tested is down-converted to the IF frequency using a local oscillator which is phase locked to the IF reference and linear mixer. The IF output of the mixer is a signal which contains contributions of the IF, RF and local oscillators, and other components in the system, including the attenuator of interest. The IF is vector null detected using the IF source for reference, yielding both phase and amplitude information with reference to the IF reference source. To remove the contribution of RF source, local oscillator, mixer and other components, a second channel, which is identical to the first and uses the same IF, RF and local oscillator source, is used in parallel with the first. The difference in the vector information is attributed to the device being tested.

For return loss measurements from 10MHz to 110MHz, VM-4A system is used in conjunction with 8721A directional bridge having 40 dB directivity (Figure 1). To cover the high frequency range up to 18 GHz, the directional couplers or reflectometer bridges with excellent directivity should be used. The directional couplers 11691D and 11692D of HP have directivities of the order of 30 dB from 2 to 8 GHz, and 26 dB from 8 to 18 GHz. A directivity of 40 dB or higher is preferable for precision measurement. For measurement of return loss, a short is connected to the test port to establish a 100% reflection reference by using the REF Control; and the second measurement is initiated through MEAS Control by connecting the device under test to the test port. When the MEAS-REF function is active, the stored reference value obtained through REF Control is substracted from the present (in process) measurement and the result displayed. Measurement resolutions of 0.1,0.01 and 0.001 dB are selectable.

Since the measurement system is microprocessor based and totally automated, uncertainties due to instrumentation setup and operation and individual measurement techniques have been eliminated or greatly reduced. As the measurement technique involves a dual channel, two-step, IF Vector substitution, the major source of measurement uncertainty lies in making repeatable insertions of the device under test in the test setup. The measurement accuracy of the VM-4A system is typically 0.02 dB/10 dB.

2. 5600 AUTOMATED SCALAR NETWORK ANALYZER SYSTEM (WILTRON):

This system, comprising a 560 Scalar Network Analyzer, 6647 Programmable Sweep Generator, SWR Autotester, Air Line, Controller, etc., also sets a new standard for microwave measurement of return (and transmission) loss. Two different setups of this system are shown in Figures 2 and 3 (Enhanced Accuracy Option P1 Method). In the setup of Figure 2 for return-loss measurements, the reflections from a short and open connected to the Autotester test port are automatically averaged and stored in the memory of network analyzer. Later the averaged residuals are subtracted from the test data obtained by connecting the device under test to the Autotester test port, to give return-loss[2]. In the setup of Figure 3 for the measurement of return-loss, a short is connected to the unbeaded end of the Air Line to establish a 100% reflection reference, and the second measurement is initiated by connecting the device under test to the Air Line. Finally, the data are manipulated by a processing algorithm, which includes a Kaiser Bessel digital filter and a Fourier transformation, to yield return-loss[3]. By employing components in the test system that are designed to reduce mismatch error and that have high directivity, hardware measurement uncertainties are greatly reduced. In Figure 3 measurement system, accuracy is enhanced by normalizing test item data using calibration data, using digital filtering and fast Fourier transform algorithms.

The overall return-loss measurement accuracy is :

SWR Autotester Accuracy + A and B Channel Accuracy

The minimum measurement resolution is 0.2 dB per division.

3. NETWORK ANALYZER SYSTEM (HP 8407 A):

This system consists of an HP 8407A Network Analyzer, HP 8601A Generator/Sweeper, and HP 8721A directional bridge[4], etc., connected as shown in Figure 4. The HP model 8721A directional bridge is principally used to make reflection measurements when characterizing 50-ohm RF networks from 0.1 to 110 MHz. To perform reflection measurement, (i) first connect an RF short to the LOAD port of the directional bridge, which means that the reflection coefficient is 1.0 at 180 degrees and the return-loss is zero dB. Establish a reference level on the HP 8412A Phase Magnitude Display; (ii) remove the RF short from the LOAD port of the directional bridge and connect the unit under test to the port and make the reflection measurement. For precise measurements use the 50 mV/dB output on the rear panel of network analyzer with an accurate Digital Voltmeter instead of the CRT display. The amplitude accuracy of network analyzer is of the order of $\pm$0.2 dB, 0.1 to 110 MHz; $\pm$0.05 dB over any 10 MHz portion. Typically, $\pm$.05 dB, 0.1 to 110 MHz for DIRECT inputs (REFERENCE level of-10 dBm).

4. SPECTRUM ANALYZER SYSTEM (HP 8566A):

The system presented here consists of an HP 8601A Generator/Sweeper and an HP 8721A directional bridge along with an HP 8566A Spectrum Analyzer for measurements up to 110 MHz (Figure 5). The measurement steps are : (i) first establish a reference level by placing a short at the LOAD port of the directional bridge, and (ii) replace the short with the terminated network and make the measurement. The resolution bandwidth, video bandwidth, span, etc., be adjusted so as to get a CRT display with low noise level and maximum amplitude at the frequency concerned. Measurement resolutions of 0.01 dB are achievable. Measurements in the high frequency range (GHz) can be accomplished through dual directional couplers or reflectometer bridges of high directivity, using high frequency sweep generators.

RESULTS

The return-loss magnitude of two devices, 50Ω20 dB Offset Wiltron model 29A50-20 (device A) and 50Ω Termination Wiltron model 28A50-1 (device B), in the low and high return-loss range is measured for the demonstration of the systems. Tables 1 and 2 list the return-loss magnitude in the range of 10 MHz to 110 MHz. The reflection coefficient magnitude calculated from return loss at each measurement frequency is plotted in Figures 6 and 7. In Table 1 the variation in values at any frequency point with four systems of measurement is not more than 1 dB except at 10 MHz where it is 1.26 dB. In Table 2, the average of variation in values is of the order of 3 dB. For low return loss measurements, VM-4A system when used with 40 dB directivity directional bridge (8721A, HP) yields measurements close to 5600 Automated Scalar Network Analyzer System (Wiltron) which uses 40 dB directivity SWR Autotesters for measurements. In Table 2 for high return loss measurements, the results through VM-4A system are in agreement at most of the frequency points with 5600 Automated Scalar Network Analyzer System (Wiltron) but more closely agree with 8407A Network Analyzer System. The random uncertainty for devices A and B is calculated based on nine and eleven degrees of freedom, respectively, and 95% confidence level.

For measurements in GHz range, a directional coupler model HP11691D is used with VM-4A system. The measurement results for both devices A and B obtained through VM-4A system and 5600 Automated Scalar Network Analyzer System (Figure 3) are given in Tables 3 and 4, respectively. In Tables 3 and 4 the difference in values at most of the frequencies is quite high. It is because of the fact that the directional coupler used is 11691D (HP) instead of the right one, 11692D (HP) dual directional coupler, and also the directivity of the coupler is less than the SWR Autotester directivity. For precise measurements with VM-4A system in high frequency range, dual directional couplers, reflectometer bridges (such as 11666A, HP), etc., having high directivity should be used.

CONCLUSIONS

The VM-4A/HO-2/4312 system provides rapid automatic return-loss measurements by automatically tuning the source to the test frequency. The VM-4A/HO-2/4312 system when used with directional bridge (HP 8721A), provides a new reflection measurement setup (10 to 110 MHz) with superior measurement performance. High frequency measurements are performed by using dual directional couplers or reflectometer bridges, etc., in the system. As the system is fully automated the measurement uncertainties are greatly reduced in comparison to other systems.

ACKNOWLEDGEMENT

The author gratefully acknowledges the support given by the Research Institute, King Fahd University of Petroleum and Minerals.

REFERENCES

1 Weinschel, Bruno O. and Weinert, Fritz K., "IF Vector Substitution Increases Accuracy", Microwave Systems News, May 1980.

2 "5600 Automated Scalar Network Analyzer System",Software User's Guide, Wiltron.

3 "Wiltron Technical Review #12", November 1982.

4. "Transmission/Reflection Kit 11652A", Operating and Service Manual, Hewlett Packard, June 1980.

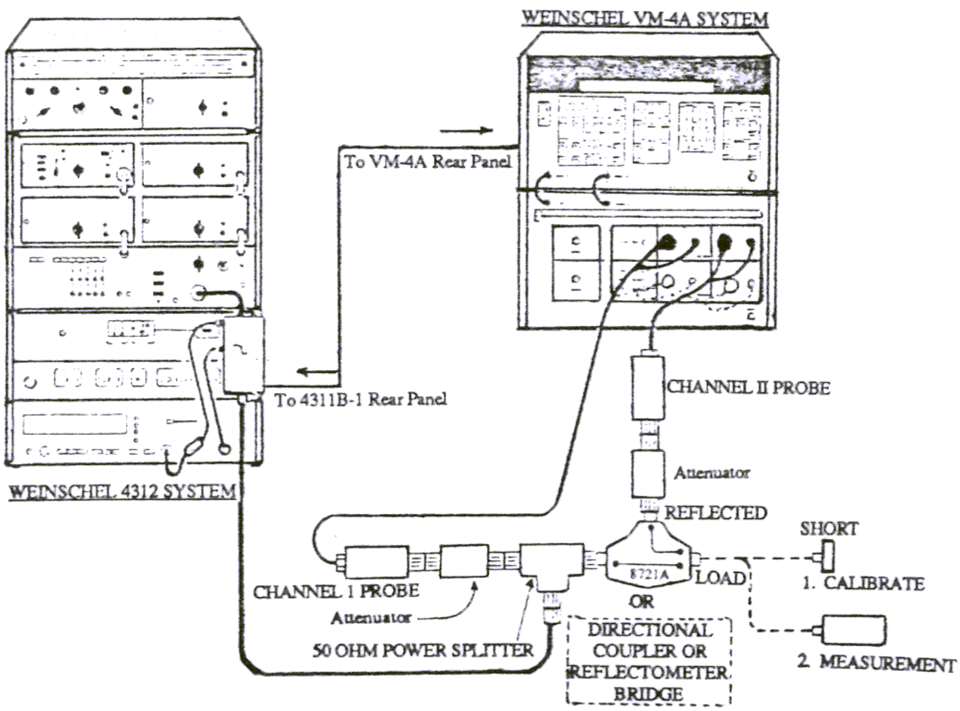

Figure 1. Return Loss Measurement Using Weinschel Engineering Model VM-4A/HO-2/4312 System

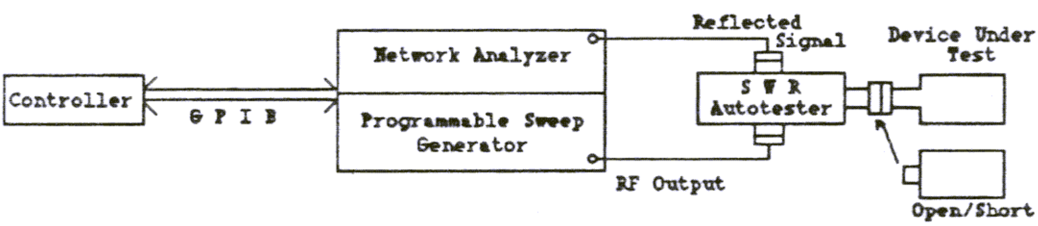

Figure 2. Return Loss Measurement Using Open/Short with SWR Autotester

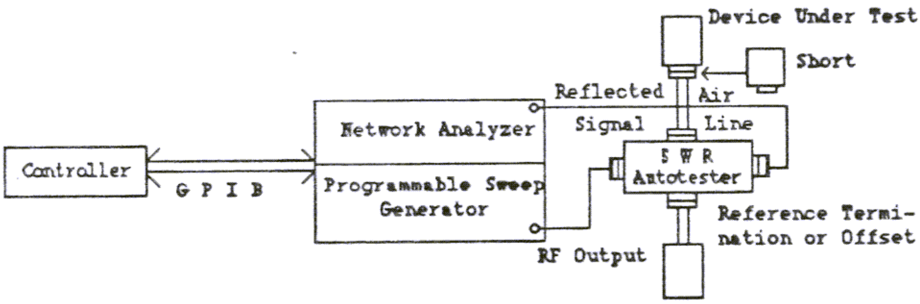

Figure 3. Enhanced Accuracy Option P1 Setup

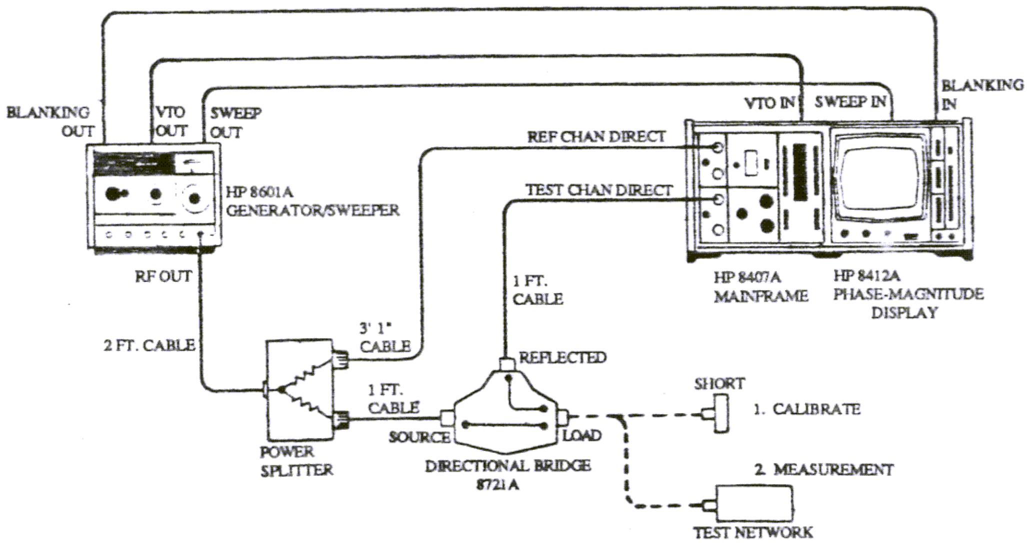

Figure 4. Return Loss Measurement Using HP 8407A Network Analyzer

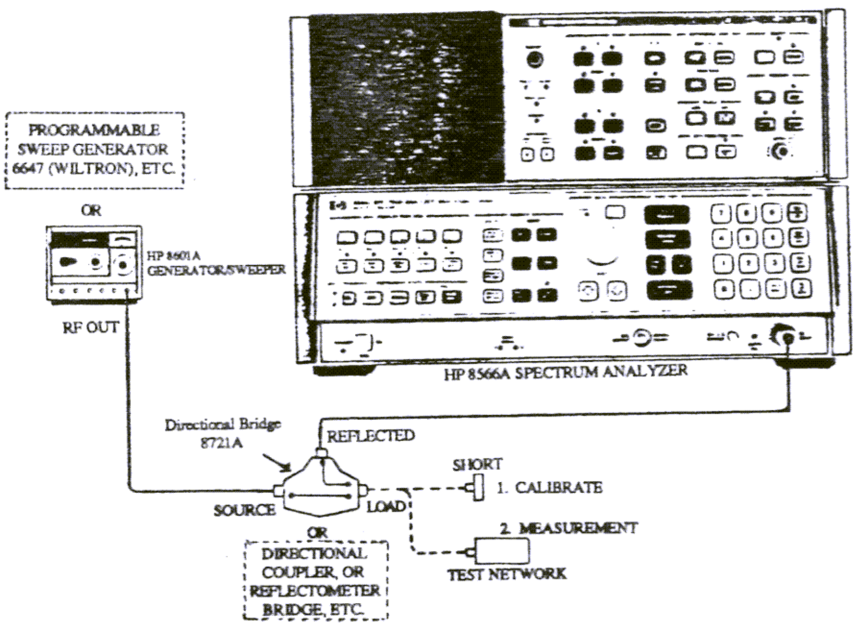

Figure 5. Return Loss Measurement Using HP 8566A Spectrum Analyzer

Table 1
Return Loss Magnitude of Device A
(50Ω 20dB Offset Model 29A50-20) From 10 to 110 MHz

Frequency (MHz)	Return Loss Magnitude (±Uncertainty) of Device A Using			
	VM-4A/HO-2/4312 System (dB)	5600 Scalar Network Analyzer System (dB)	8407A Network Analyzer System (dB)	8566A Spectrum Analyzer System (dB)
10.0	18.941(±.004)	19.768(±.007)	20.201(±.002)	20.010(±.053)
20.0	19.213(±.003)	19.813(±.006)	20.162(±.004)	19.930(±.059)
30.0	19.160(±.003)	19.817(±.008)	20.143(±.002)	19.890(±.071)
40.0	19.262(±.003)	19.816(±.009)	20.134(±.001)	19.780(±.056)
50.0	19.368(±.003)	19.804(±.008)	20.142(±.003)	19.750(±.038)
60.0	19.480(±.003)	19.822(±.008)	20.147(±.001)	19.840(±.037)
70.0	19.608(±.003)	19.824(±.007)	20.161(±.011)	19.830(±.035)
80.0	19.847(±.003)	19.832(±.011)	20.180(±.002)	19.790(±.065)
90.0	20.137(±.002)	19.836(±.007)	20.167(±.002)	19.820(±.051)
100.0	20.482(±.003)	19.840(±.007)	20.149(±.003)	19.960(±.055)
110.0	20.831(±.003)	19.843(±.008)	20.178(±.002)	20.090(±.067)

Table 2
Return Loss Magnitude of Device B
(50Ω Termination Model 28A50-1) From 10 to 110 MHz

Frequency (MHz)	Return Loss Magnitude (±Uncertainty) of Device B Using			
	VM-4A/HO-2/4312 System (dB)	5600 Scalar Network Analyzer System (dB)	8407A Network Analyzer System (dB)	8566A Spectrum Analyzer System (dB)
10.0	53.505(±.421)	45.465(±.484)	54.467(±.069)	53.258(±.542)
20.0	51.187(±.222)	48.604(±.316)	51.838(±.011)	51.042(±.171)
30.0	48.942(±.130)	44.354(±.102)	49.534(±.009)	48.817(±.046)
40.0	47.370(±.089)	44.481(±.121)	47.726(±.006)	46.775(±.082)
50.0	46.233(±.069)	44.386(±.096)	46.452(±.025)	45.458(±.063)
60.0	45.469(±.059)	45.147(±.099)	45.470(±.004)	44.550(±.051)
70.0	45.029(±.050)	45.305(±.158)	44.904(±.014)	43.958(±.074)
80.0	44.960(±.047)	45.484(±.163)	44.498(±.009)	43.525(±.050)
90.0	45.162(±.043)	45.616(±.129)	44.223(±.013)	43.338(±.056)
100.0	45.590(±.042)	45.753(±.139)	44.205(±.026)	43.342(±.042)
110.0	46.111(±.047)	45.827(±.112)	44.299(±.039)	43.525(±.067)

Table 3
Return Loss Magnitude of Device A (50Ω 20dB Offset Model 29A50-20) from 2 to 14 GHz

Frequency (GHz)	Return Loss Magnitude (±Uncertainty) of Device A Using		Difference $= \lvert X_1 - X_2 \rvert$
	VM-4A/HO-2/4312 System (dB) 'X_1'	5600 Scalar Network Analyzer System (dB) 'X_2'	
2.0	22.040(±.076)	20.380(±.004)	1.660
3.0	21.182(±.060)	20.191(±.002)	0.991
4.0	19.848(±.134)	19.851(±.004)	0.003
5.0	19.043(±.404)	19.896(±.005)	0.853
6.0	19.156(±.369)	20.193(±.004)	1.037
7.0	21.397(±.314)	20.315(±.003)	1.082
8.0	20.546(±.091)	19.951(±.006)	0.595
9.0	19.664(±.106)	19.596(±.005)	0.068
10.0	20.729(±.402)	19.528(±.008)	1.201
11.0	16.779(±.110)	19.704(±.009)	2.925
12.0	17.300(±.027)	19.468(±.008)	2.168
13.0	16.507(±.024)	19.171(±.012)	2.664
14.0	18.655(±.023)	19.425(±.008)	0.770

Table 4
Return Loss Magnitude of Device B (50Ω Termination Model 28A50-1) from 2 to 14 GHz

Frequency (GHz)	Return-Loss Magnitude (±Uncertainty) of Device B Using		Difference $= \lvert X_3 - X_4 \rvert$
	VM-4A/HO-2/4312 System (dB) 'X_3'	5600 Scalar Network Analyzer System (dB) 'X_4'	
2.0	36.014(±.047)	40.646(±.251)	4.632
3.0	50.368(±.292)	41.527(±.220)	8.841
4.0	32.687(±.383)	43.616(±.214)	10.929
5.0	33.879(±.201)	44.481(±.365)	10.602
6.0	40.064(±.940)	41.531(±.255)	1.467
7.0	36.063(±.287)	37.585(±.168)	1.522
8.0	29.904(±.340)	34.340(±.189)	4.436
9.0	32.054(±.531)	32.776(±.152)	0.722
10.0	31.062(±.317)	31.252(±.154)	0.190
11.0	23.149(±.275)	31.409(±.193)	8.260
12.0	27.233(±.327)	32.857(±.228)	5.624
13.0	30.270(±.645)	36.879(±.346)	6.609
14.0	29.583(±.146)	42.672(±1.306)	13.089

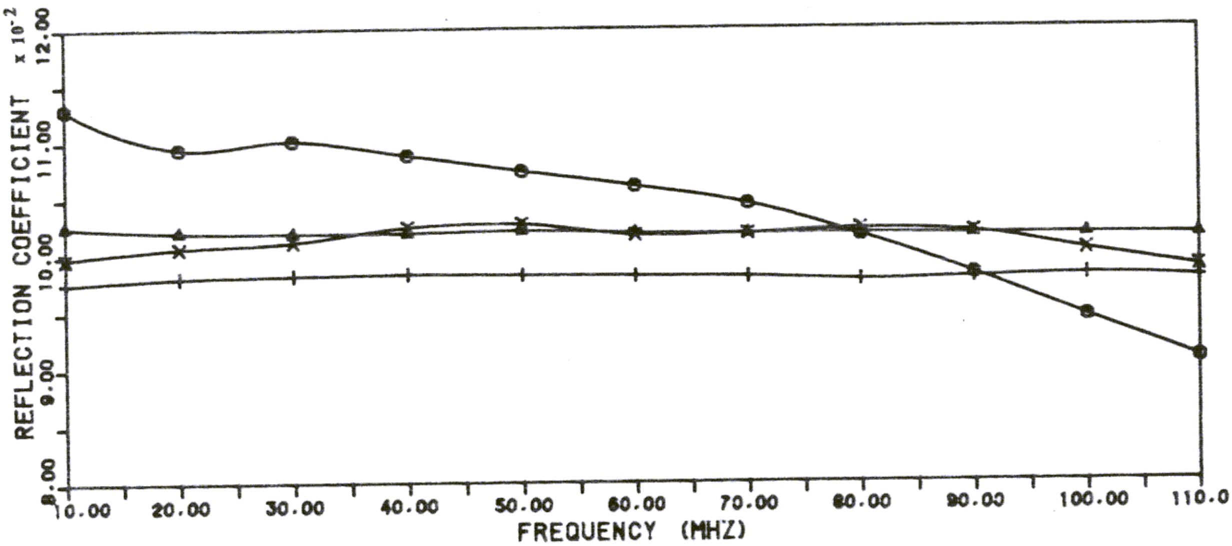

Figure 6. Reflection Coefficient magnitude of device A (50Ω 20dB Offset model 29A50-20) using (i) VM4A/HO-2/4312 System (O), (ii) 5600 Automated Scalar Network Analyzer System (▲), (iii) 8407A Network Analyzer System (+), and (iv) 8566A Spectrum Analyzer System (x).

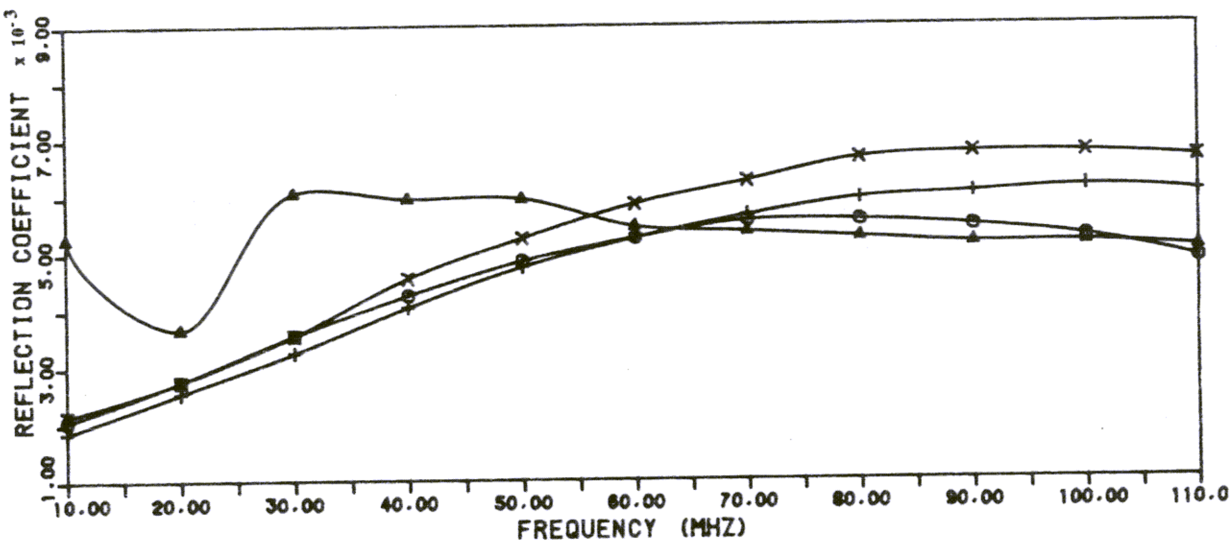

Figure 7. Reflection Coefficient magnitude of device B (50Ω Termination Model 28A50-1) using (i) VM-4A/HO-2/4312 System (O), (ii) 5600 Automated Scalar Network Analyzer System (▲), (iii) 8407A Network Analyzer System (+), and (iv) 8566A Spectrum Analyzer System (x).