Larsen Antennas

White Paper: NMOHF Antenna Mounts

Report from research and testing conducted May 25, 2006

Aaron B. Logan
Test Engineer

Date: 6/12/06

3611 NE 112th Avenue
Vancouver, WA 98682

Phone: 360-944-7551
Fax: 360-944-7556
www.larsen-antennas.com

Abstract:

The most popular vehicle mount is the NMO, or “new Motorola” mount. This product is styled after the industry standard TAD/TAE 3/4”-hole mount. Larsen developed the NMOHF (high frequency mount), a totally redesigned standard NMO mount, which boasts a variety of innovative features. Of particular interest is the claim the NMOHF, especially in the “low-loss” configuration, provides superior impedance matching at frequencies above 1 GHz.

This impedance match improvement was designed into the new NMOHF mount by implementing two unique characteristics. First, the input of the mount has changed to coaxial-style interface. The ground is crimped to the mount like a standard RG-58 connector and the center contact is soldered and fully sealed. Out of the package, this is known as the “standard” configuration.

The second design feature is the integration of a BNC/TNC-style interface hidden beneath the standard configuration. To reveal this interface, the center contact pin and insulator are removed. This is referred to as the “low-loss” configuration.

To validate the superiority of the NMOHF, testing was performed comparing the NMOB industry standard to the NMOHF in the standard configuration, and the NMOHF in the low-loss configuration. Primarily of interest is the insertion loss of the mounts and the reflections caused by mismatch.

Results:
Maximum S21 Insertion loss while sweeping from 100 MHz to 3 GHz resulted in the following:

NMOB (standard)	-5.45 dB
NMOHF (standard	-2.87 dB
NMOHF (low-loss	-0.35 dB

Maximum S11 Reflection while sweeping from 100 MHz to 3 GHz resulted in the following:

	Γ	VSWR	RL	ML	% Reflected
NMO B (standard)	0.59	3.85:1	-4.62 dB	1.84 dB	34.55 %
NMO HF (standard)	0.38	2.22:1	-8.41 dB	0.68 dB	14.41 %
NMO HF (low-loss)	0.14	1.32:1	-17.26 dB	0.08 dB	1.88 %

Testing proves changing from the standard NMOB to the NMOHF offers almost 50% better impedance match. Using the NMOHF in the low-loss configuration offers the best performance for all products above 1 GHz.

Table of Contents

1. Introduction and Background

Antennas, used for two-way communications, are everywhere. No matter where you look, they are used for various applications –portable antennas used on hand-held radios, tall towers housing cellular repeaters, indoor wireless routers found in many businesses and homes. Antennas are abundant.

Perhaps one of the best places to spy an antenna is on a vehicle. A stylish ride may have a cellular antenna mounted on the rear window. An amateur radio operator may have a magnetic mount antenna on the rear trunk. A trucker using a CB radio may have an antenna mounted on the bumper of an 18-wheeler. Police cars and other municipalities are known for being littered with multiple roof-mounted antennas.

The most popular vehicle mount is the NMO or "new Motorola" mount. This permanent roof-styled mount is styled after the industry standard TAD/TAE 3/4"-hole mount. Larsen's NMO version consists of a nickel plated brass bushing and silver plated center contact for maximum conductivity and corrosion resistance. The standard hardware for this mount is offered as part number NMOB.

Antennas operating above 1 GHz require a better impedance match than traditional NMO mounts can provide. To meet this requirement, Larsen developed the NMOHF, a totally redesigned NMO mount with a variety of innovative features such as improved the impedance match and reduced insertion losses associated with industry standard mounts.

In an effort verify these claims, a simple study was performed on the NMOB, the NMOHF in its standard configuration, and the NMOHF in the low-loss configuration.

2. Theory

The feed point of roof-mounted antennas is at the base where the antenna threads onto the mount. Ideally, this interface should perform like a perfect transmission line where all the energy passes through to the mount and then transmitted by the antenna. In a perfect world, there would be no insertion loss or mismatch reflections.

Insertion loss relates to the amount of loss resulting from the insertion of a device in a transmission line. This loss is expressed as the reciprocal of the ratio of the signal power delivered at the end of the device when compared to the signal power delivered at the beginning of the same device. This loss is typically expressed in dB – the lower the value, the lower the loss through the device. Ideally, this value would be zero.

The term "reflections," is a general term used to describe the amount of energy reflected back to the energy source due to an imbalance in the characteristic impedance of two devices such as a transmission line and a connector, or in this case a transmission line and the NMO mount. This mismatch can be expressed in a number of ways such as VSWR, Return Loss, Reflection Coefficient and Mismatch Loss.

To simplify and visualize this concept, refer to Figure 1 below.

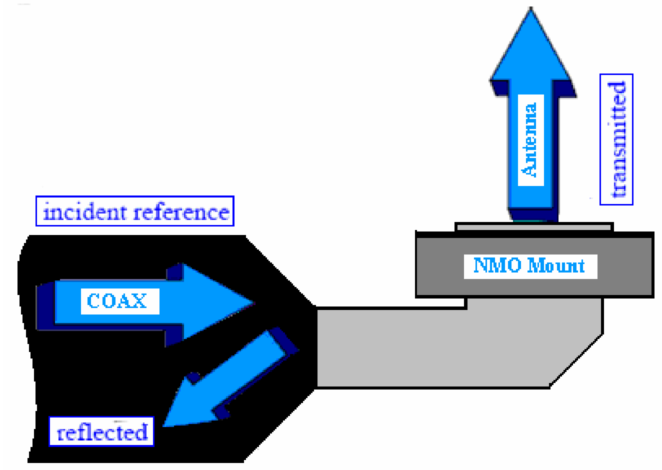


Figure 1

As the incident power, or forward power, meets the mount, most of the energy will continue through the mount and be delivered to the antenna to be radiated. However, due to impedance differences, or mismatch, some of this power is reflected back towards the power source. In addition to this reflected energy, some energy will be used by the mount and is measured as insertion loss. These effects are frequency dependent and increase noticeably above 1 GHz.

The Mount

The NMOHF mount offers a better impedance match at the input of the mount where the transmission line attaches to the mount and at the output of mount where the antenna is installed. The input was improved by making the mount installation similar to that of standard RG-58 style connectors. This approach allows for a better impedance match to the transmission line reducing reflections. Also to be noted is that the NMOHF offers a water resistant install – a performance characteristic improvement the industry standard cannot compete against.

The output of the mount was improved by employing an innovative, removable insulator and center contact pin revealing a BNC/TNC-style interface. Keeping the insulator and pin in place, known as the standard configuration, allows use of the NMOHF for antennas below 1 GHz. By removing these two components, known as the low-loss configuration, the user can switch to higher-frequency antennas for 1 GHz and up. This improvement, along with the connector style input reduces insertion loss dramatically in the high-frequency configuration.

The mount can be used in the standard configuration for all NMO-style antennas or can be used for Larsen specific high frequency antennas in a “low-loss” configuration. Both configurations were tested.

Application Example.
Suppose an Install Technician measures the forward and reflected power of an antenna system. Without knowing the details of the testing, knowing only the forward and reflected power, we can derive VSWR, Return Loss, Reflection Coefficient, and Mismatch Loss.

Given the measured results:

$P_{(forward)} = 25$ W
$P_{(reflected)} = 3$ W

To determine the Return Loss (RL):

$$RL(dB) = 10\log\frac{P(reflected)}{P(forward)}, \; = 10\log\frac{3W}{25W} = -9.21dB$$

To express this return loss as a Reflection Coefficient (Γ):

$$\Gamma = 10\wedge\frac{RL}{20}, \; = 10\wedge\frac{-9.21dB}{20} = 0.35$$

To determine the Voltage Standing Wave Ratio (VSWR):

$$VSWR = \frac{1+\Gamma}{1-\Gamma}, \; = \frac{1+0.35}{1-0.35} = 2.06:1$$

To determine the Mismatch Loss (ML):

$$ML(dB) = -10\log(1-\Gamma\wedge 2), \; = -10\log(1-0.35\wedge 2) = 0.56dB$$

3. Description of Experimental Setup

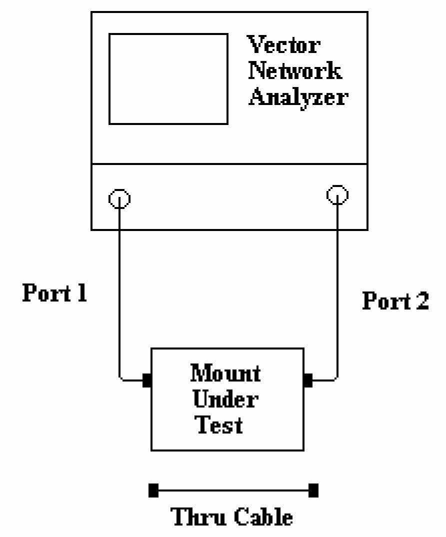


Figure 2

Testing was performed using a Vector Network Analyzer. Refer to Figure 2

- Network Analyzer setup parameters:

Start Frequency:	100 MHz
Stop Frequency:	3000 MHz
Number Points:	201
Calibration Type:	OSLT – Full 2-port
Power Reference:	0 dBm
Sweep Type:	Continuous

- Both the Reflection Port and Transmission Port have matched N Male to N Male cable assemblies.
- Full 2-port calibration performed using a 3.5 mm SMA Calibration Kit.
- SMA Male to N Female adapter at the end of Port 2 Test Cable.
- NMO to N Female Radiall adapter used during test.
- NMOHF to SMA Female Radiall test adapter used during test.
- SMA Male to N Female Radiall test adapter at the end of Port 1 Test Cable (during NMOHF test).

4. List of Equipment Used

DESCRIPTION	QTY	SERIAL NUMBER	CALIBRATION
Agilent E8356A	1	US40350104	7 MAR 2007
Agilent 85052D	1	2919A03225	7 MAR 2007
MINI-Circuit CBL2FTNMNM	2	4572 & 4579	N/A
NF to SMA M adaptor	2	N/A	N/A
Larsen NMOHF to SMA F	1	N/A	N/A
Larsen NMO to N F	1	N/A	N/A

PHOTOGRAPH OF SAMPLES

NOTE: To repeat this test, the cable length of both mounts must be identical.

The “thru” cable is used to negate the effects of the transmission line installed on the mount assembly.

5. Procedure

Sufficient information is provided to allow the reader to repeat the experiment in a similar manner.

1. Network Analyzer Setup: Set the start/stop frequencies for 100 MHz to 3 GHz. The number of points is set at 201. The power reference level is set at 0 dBm with a continuous sweep measurement.

2. Install test cables on the N Female Ports of the Network Analyzer. Install the N Female to SMA Male adapters. Perform a full 2-Port calibration using the mechanical standards in the 85052D calibration kit. During the calibration, when prompted to install the "thru" standard, use the "thru" cable in Figure 2

3. Remove the adapter on Port 1 test cable and install the NMO to N Female adapter. Change measurement format to S11 Smith Chart. Turn Port Extension "on" and zero the adapter out of the measurement.

4. Change measurement type to S11 "SWR". Install NMOB mount assembly onto the adapter, and attach the test cable on Port 2. Record the results. Change measurement format to Log Mag for return loss and record results. Change measurement type to S21 Log Mag and record the results.

5. Remove NMOB mount assembly from the test cables and adapters and install NMOHF, with the insulator and contact pin in place. Change measurement format to S11 "SWR" and record the results. Change measurement format to Log Mag and record results. Change measurement type to S21 Log Mag and record results.

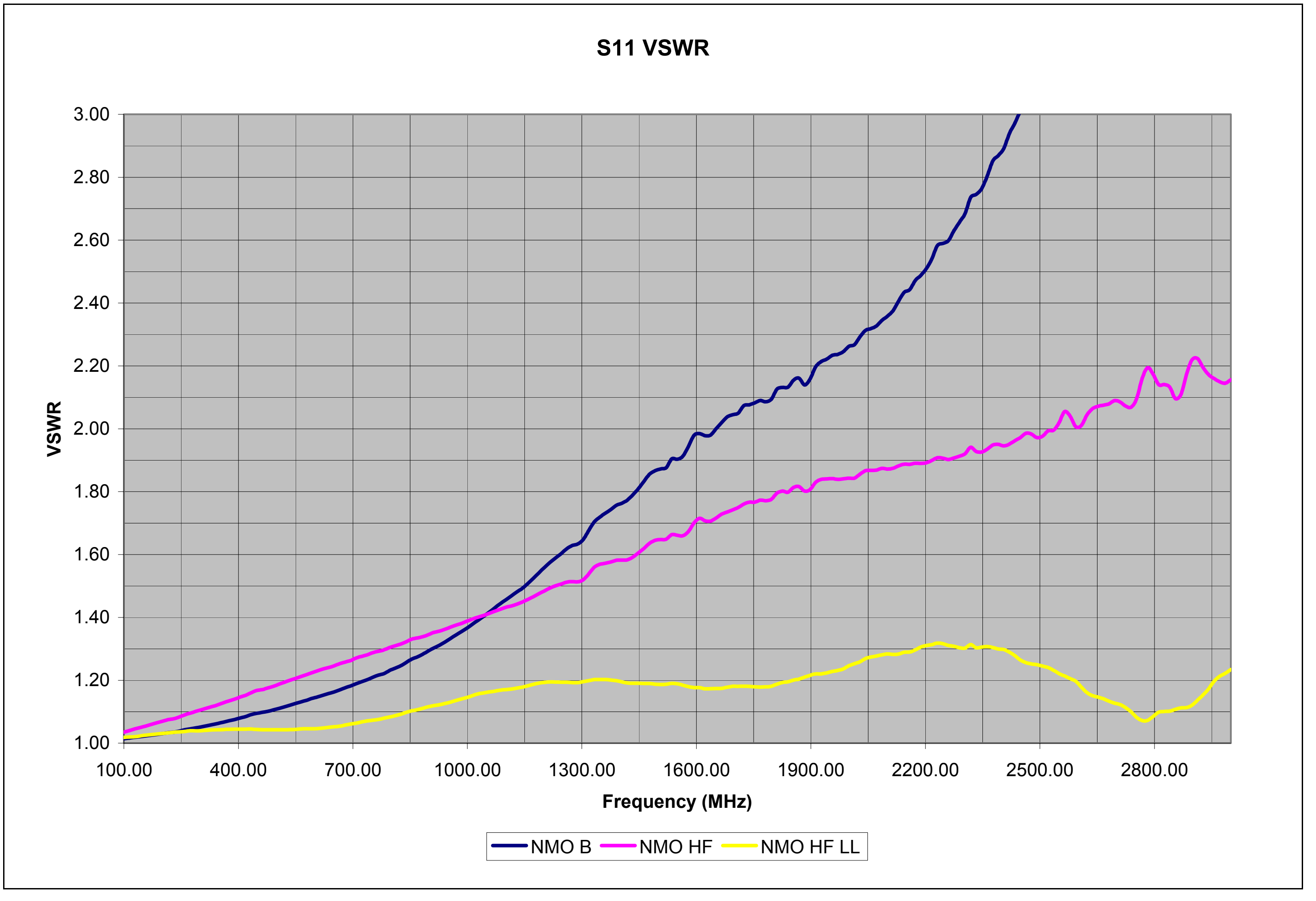
6. Disconnect the NMO to N adapter and reinstall the N Female to SMA Male adapter. Install the NMOHF to SMA F adapter. Change measurement type to S11 Smith Chart and adjust Port Extension to zero Port 1. Remove the insulator and center contact pin to reveal BNC/TNC interface on the NMOHF mount assembly. Connect to NMOHF adapter and test cable on Port 2.

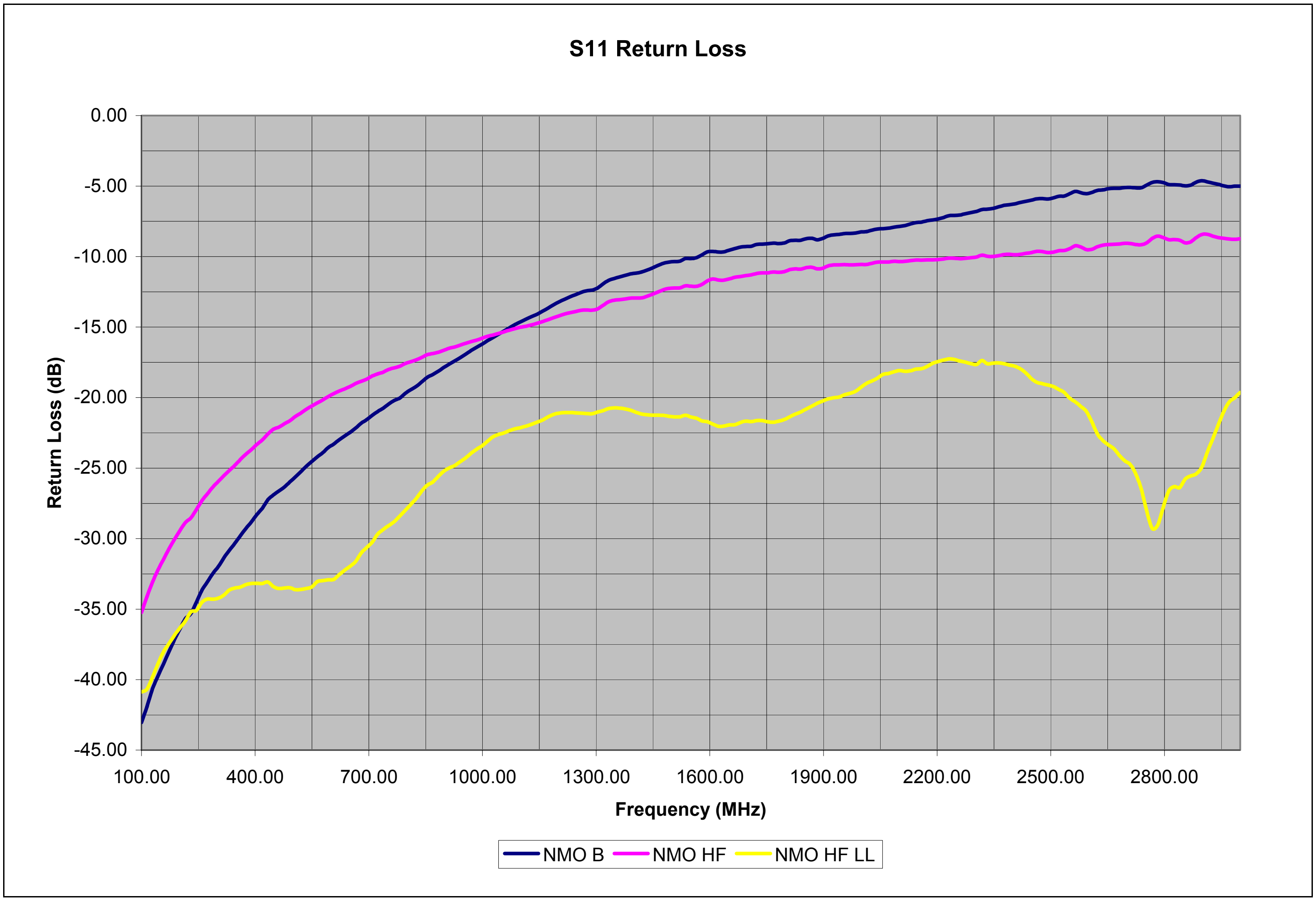
7. Change measurement format to S11 "SWR" and record the results. Change measurement format to Log Mag and record results. Change measurement type to S21 Log Mag and record results.

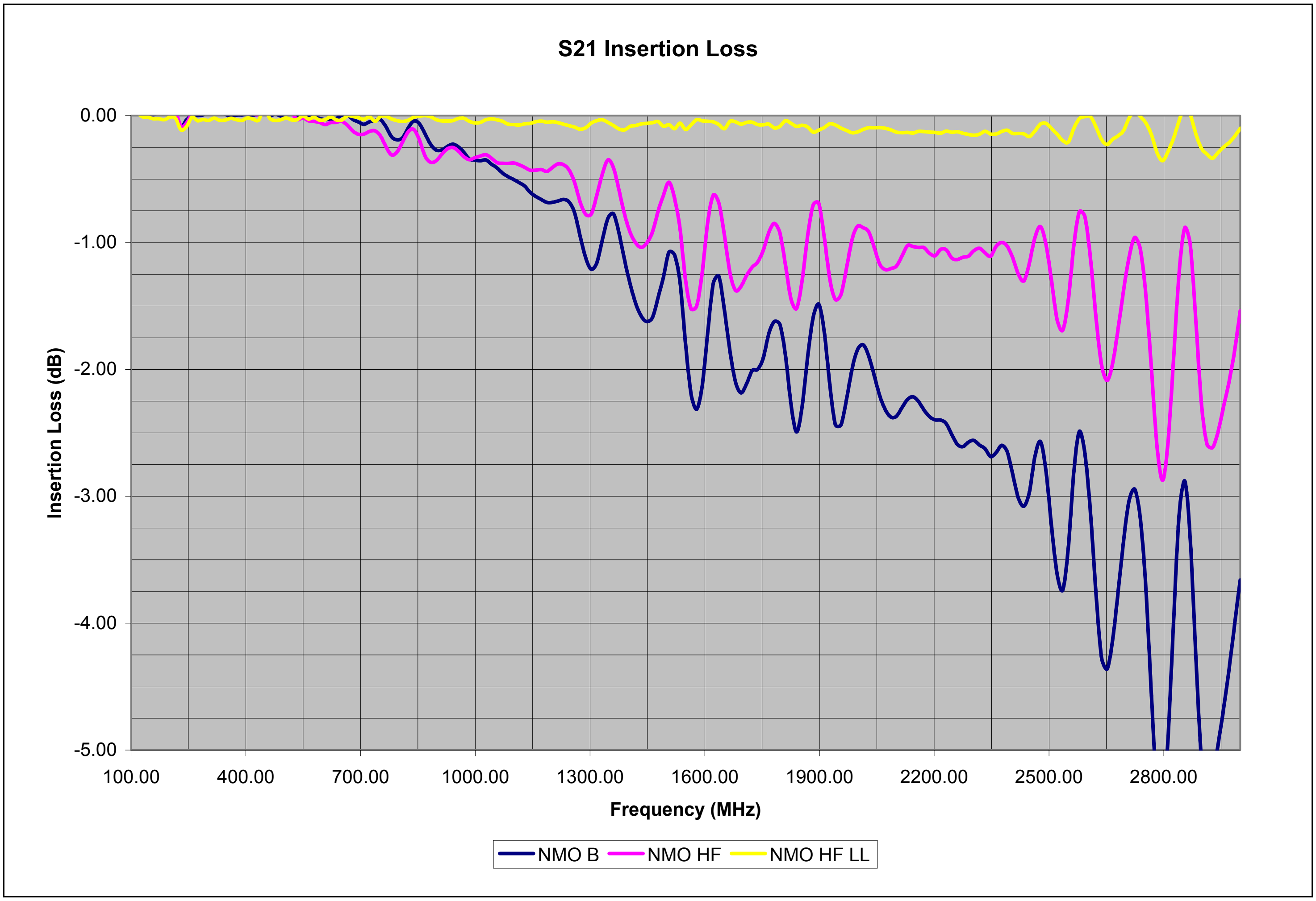
6. Data

All the pertinent raw data obtained during testing is presented as graphs instead of the original ASCII format. This is to keep the presentation of the information simple.

Note: In the series table, NMOB and NMOHF are tested in the same configuration. NMOHF LL represents the NMOHF tested in the low-loss configuration.



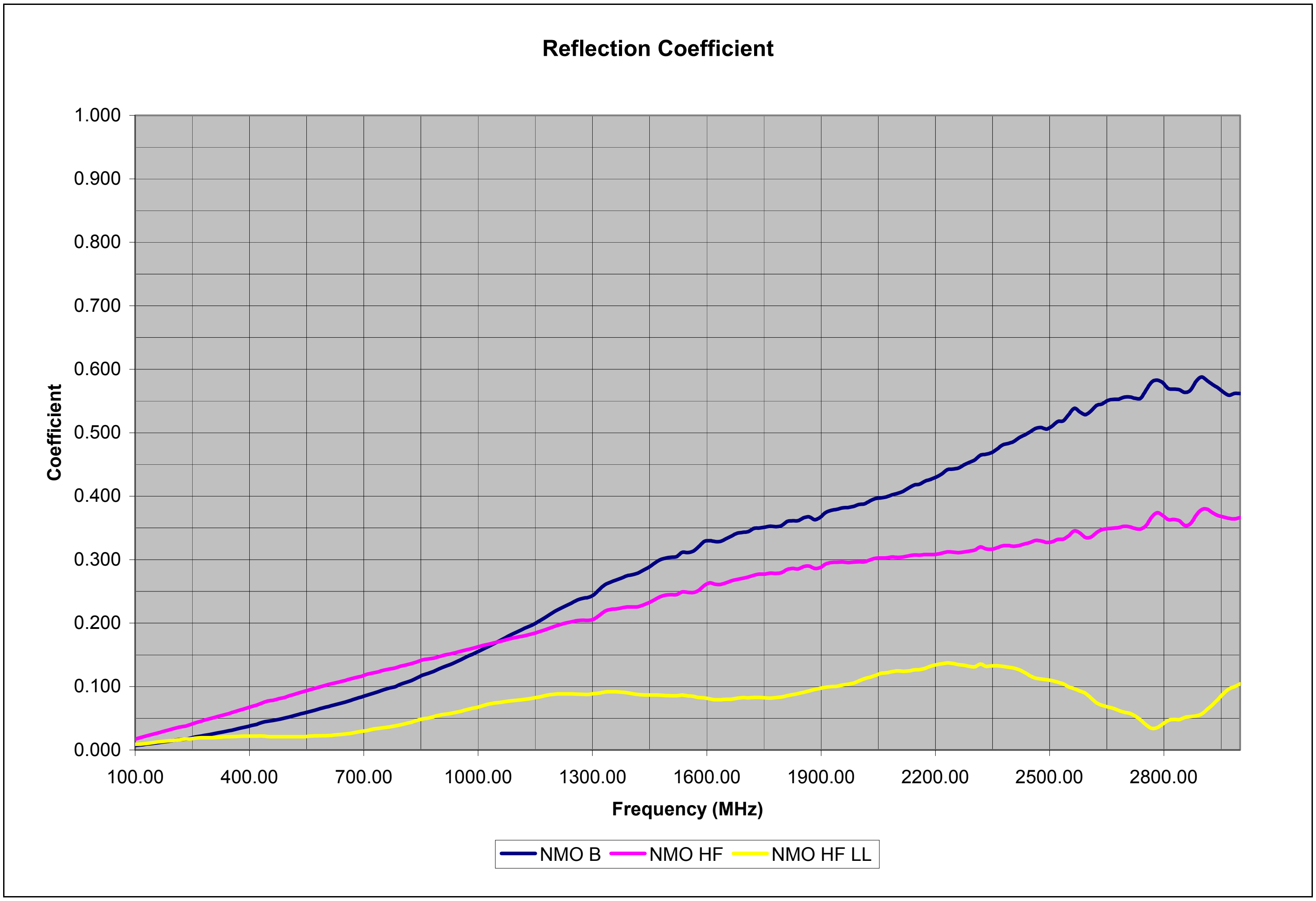

S11 Return Loss
Return Loss (dB)
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
100.00
400.00
700.00
1000.00
1300.00
1600.00
1900.00
2200.00
2500.00
2800.00
Frequency (MHz)
NMO B
NMO HF
NMO HF LL


S21 Insertion Loss
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
Insertion Loss (dB)
100.00
400.00
700.00
1000.00
1300.00
1600.00
1900.00
2200.00
2500.00
2800.00
Frequency (MHz)
NMO B
NMO HF
NMO HF LL

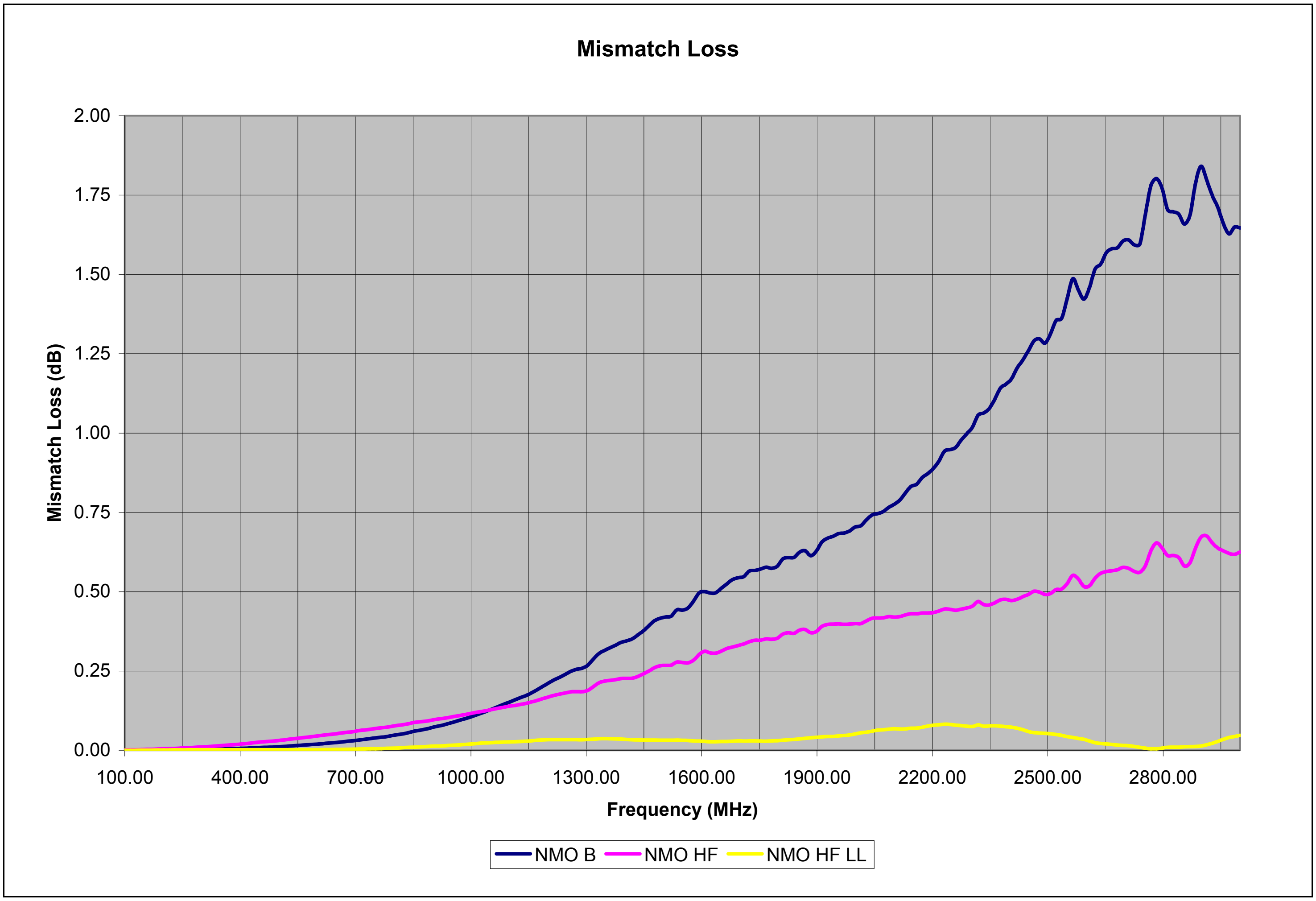
7. Analysis of Data

To determine the mismatch loss and reflection coefficients, the following formulas were applied to the raw data and plotted for analysis.

Reflection Coefficient	Mismatch Loss
$\Gamma = 10\wedge \frac{RL}{20}$	$ML(dB) = -10\log(1 - \Gamma \wedge 2)$



The Reflection Coefficient, or Γ, will be between 0 and 1. If measured Γ is 0, all energy is accepted into the mount. As Γ increases toward 1, more energy is being reflected to the source. At 1, all energy is reflected.



The mismatch loss is a measure of how much of the transmitted power is attenuated due to reflections. Not many Install Technicians use this value for reference, as it is most commonly used to derive a total measurement uncertainly within a system.

Example:

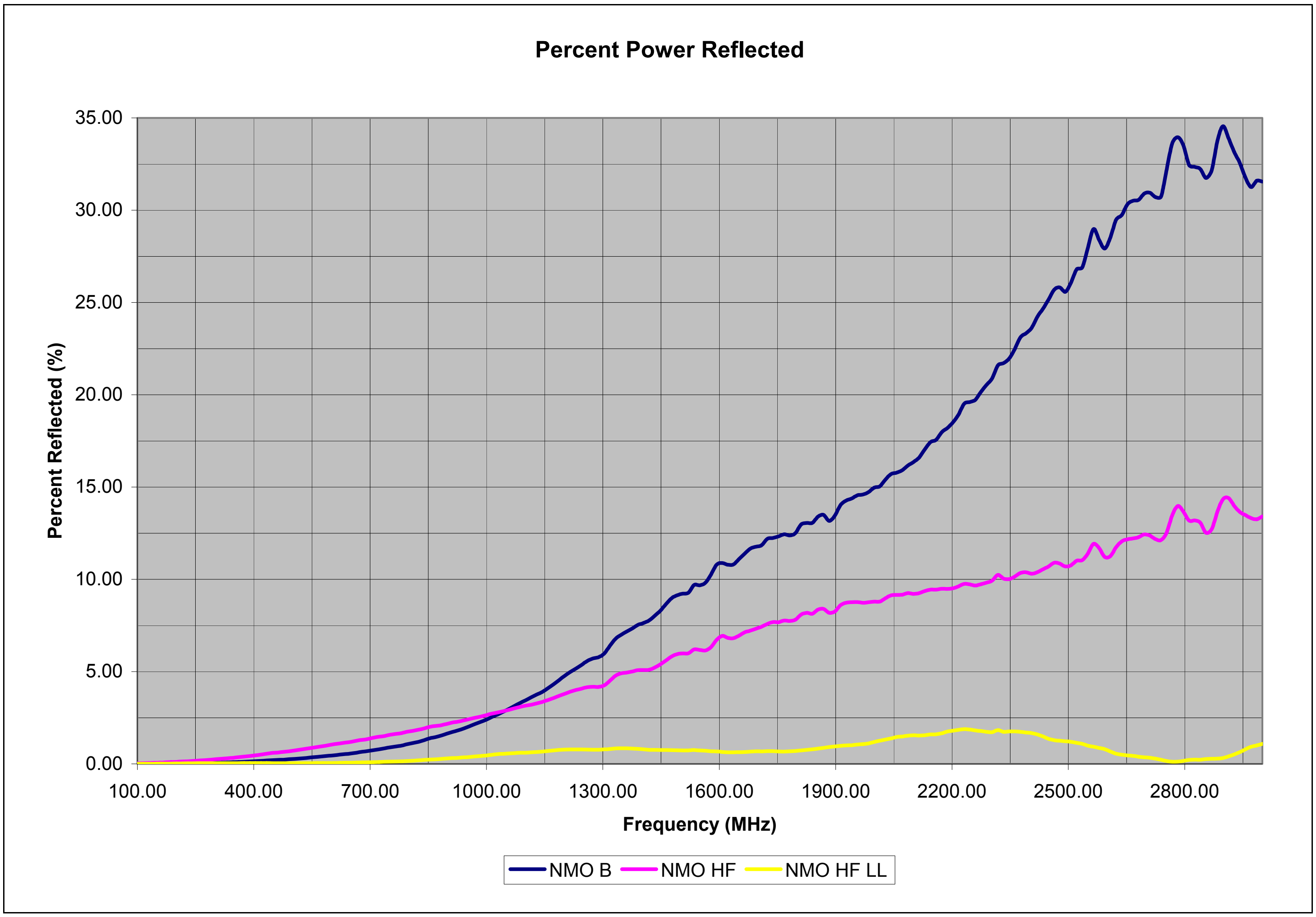
VSWR	Mismatch Loss
1.5:1	0.177 dB
2.0:1	0.512 dB
2.5:1	0.880
3.0:1	1.25 dB

8. Discussion of Results

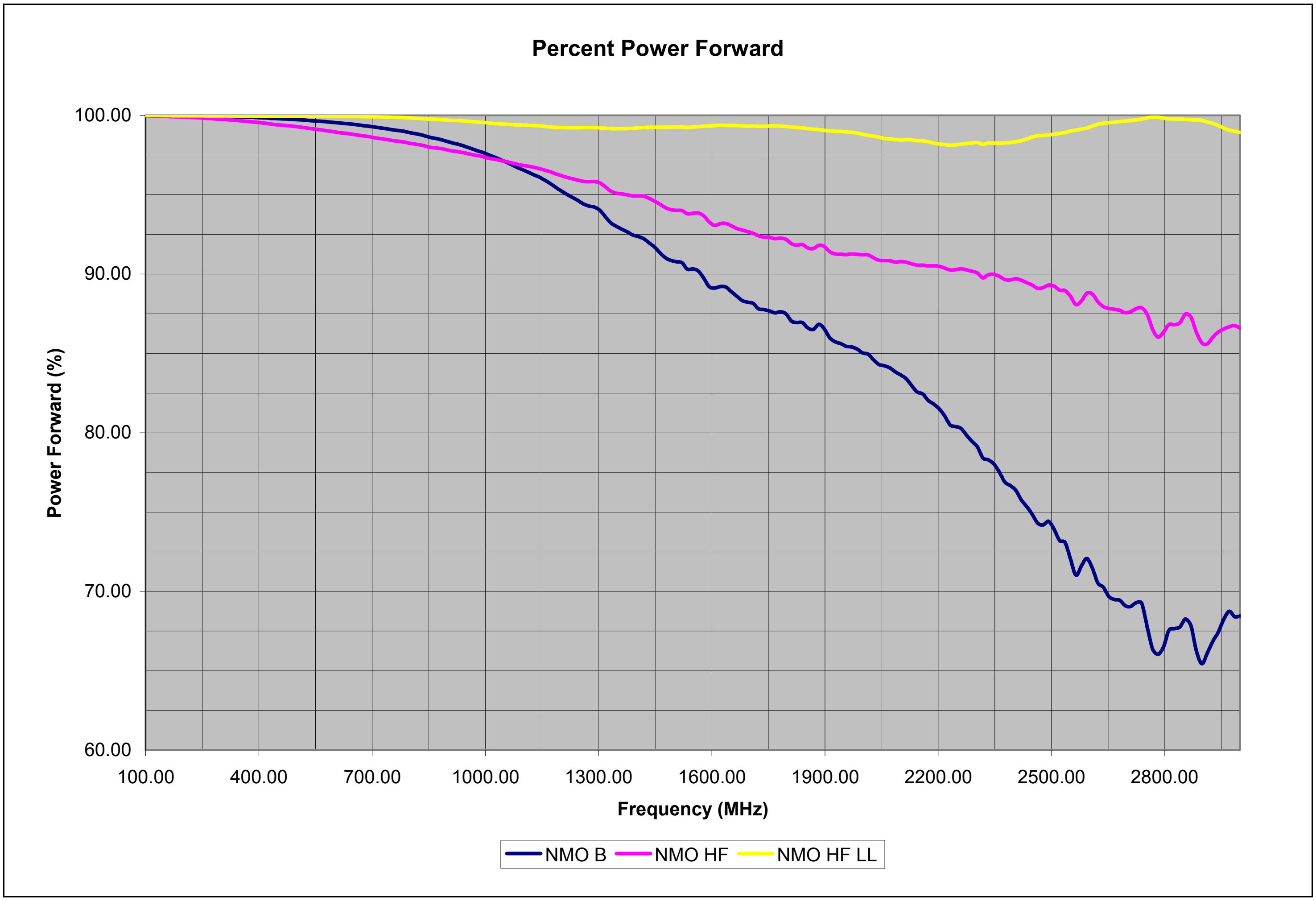
What does all this ***really*** mean? From an Install Technician's point of view, it's all about power. How much power will be delivered to the antenna directly relates to how well the energy passes through the mount.

The S11 reflection parameter can be viewed from a number of perspectives. Whether the focus is VSWR, Return Loss, Mismatch Loss, Reflection Coefficient, or Return Loss, they are all ways of representing the same thing – how well the mount accepts the RF power into the mount versus how much power is being reflected back to the RF source.

To illustrate these results in a percentage of energy, review the following.



At 1 GHz, approximately 2.5% of the total power is being reflected to the source with the NMOB and NMOHF (standard). The NMOHF (low-loss) reflects only 0.45%!



As the data indicates, the NMOB and NMOHF are acceptable for frequencies below 1 GHz. However, once the product selection moves to higher frequencies, such as GPS (1575.4 MHz) or PCS (1850-1990 MHz), the amount of energy reflected by the mount itself become even more pronounced.

9. Conclusions

The intent of the NMOHF mount is to reduce losses in the mount by improving the input and output of the mount. The data from testing the NMOB and the NMOHF in the standard configuration shows a better impedance match with the NMOHF. This is directly attributed to the connector-style installation process of the mount to the transmission line.

When this feature is combined with the low-loss configuration of the BNC/TNC style interface, reflections are minimized and more than 98% of the Power incident on the mount is delivered to the antenna up to 3 GHz. The NMOHF is clearly superior to the standard NMO mount.

10. Resources

- Carr, Joseph J. (2002) *Practical Radio Frequency Test & Measurement: A Technician's Handbook*. Burlington, MA: Newnes
- Bucher, Jay L. (2004) *The Metrology Handbook.* Milwaukee, WI: ASQ (American Society For Quality)
- Agilent (2002) *2002 Back To Basics Seminar.* USA, Agilent Technologies
- Agilent Application Note 5965-7917E (2004) *Network Analyzer Basics*. , Agilent Technologies Inc.
- Hewlett-Packard Application Note 1287-1 (1997) *Understanding the Fundamental Principles of Vector Network Analysis.* Englewood, CO
- Hewlett-Packard Application Note 1287-3 (1997) *Applying Error Correction to Network Analyzer Measurements.* Englewood, CO
- Green, Robert and Slaughter, Jeff (2001) *Managing RF Signals in Test Systems*, Evaluation Engineering, Nelson Publishing (http://www.evaluationengineering.com/archive/articles/1201rf.htm)
- Sischka, Frank *3.3.3.1 Basics of S-Parameters, Part 1*, Characterization Handbook 1SBASIC.doc 18.03.02 (http://eesof.tm.agilent.com/docs/iccap2002/MDLGBOOK/1MEASUREMENTS/3VNA/3SPAR/1SparBasics_1.pdf)
- Microwave Encyclopedia (2005) *VSWR*, Microwave 101.com, P-N Designs (http://www.microwaves101.com/encyclopedia/vswr.cfm)
- US Navy (2001) Voltage *Standing Wave Ratio (VSWR) / Reflection Coefficient / Return Loss / Mismatch Loss*, EW & Radar Systems Engineering Handbook (https://ewhdbks.mugu.navy.mil/VSWR.htm)
- Agilent Metrology Forum (Technical Articles) *Use of Adapters in Network Analysis,* Agilent Technologies (http://www.agilent.com/metrology/adapter.shtml)