

Evaluation of Commercial Phase Shifters for Cryogenic Applications

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Cavity Impedance Matching

Impedance Control for Critically Coupled Cavities

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Abstract—Cavity resonators are often used in low phase noise oscillators that utilize carrier suppression. These oscillators are employed in systems that measure phase noise in frequencies as high as 100 GHz. In order to achieve the maximum suppression needed in these low noise designs, the cavity must be operated at critical coupling. However, this large coupling level loads the cavity, which significantly lowers its quality factor and shifts its resonant frequency. In this paper, we present a matching technique that can be used to minimize these loading effects by controlling the input impedance of the cavity and optimizing its response at resonance, thus producing the maximum amount of carrier suppression.

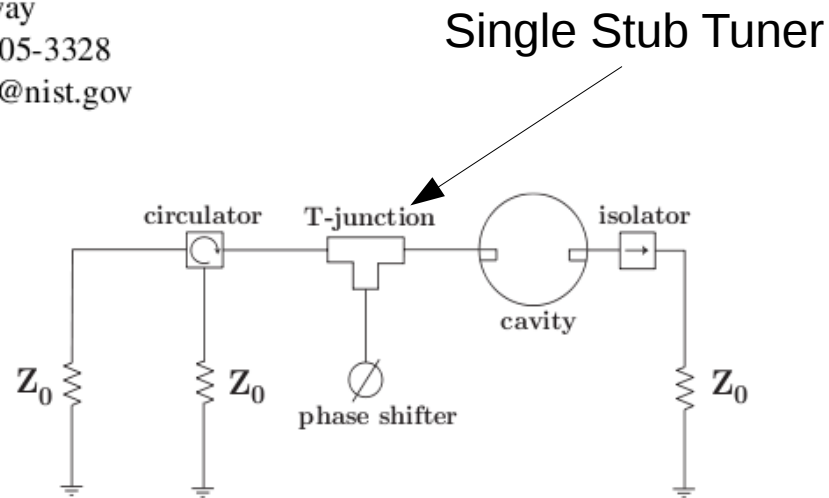


Fig. 1. Simplified diagram of the cavity circuit with input matching. Z_0 is the system's characteristic impedance.

Circuit Diagram of a Typical Varactor Based Phase Shifter

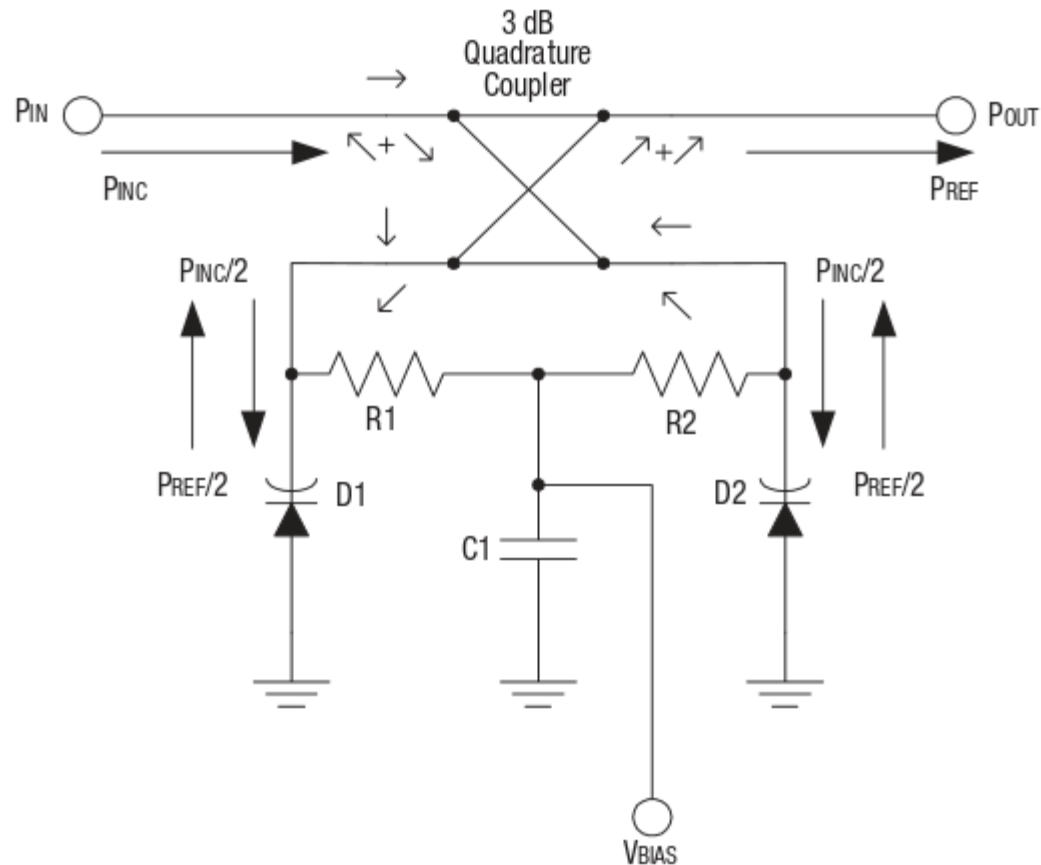


Figure 1. Typical Phase Shifter Design

Skyworks, Inc.

Commercial Phase Shifter Candidates

Surface Mount Phase Shifter

50Ω 360° Voltage Variable 800 to 1500 MHz

Maximum Ratings

Operating Temperature	-40°C to 85°C
Storage Temperature	-55°C to 100°C
RF Input Power	20 dBm max.
Control Voltage	20V

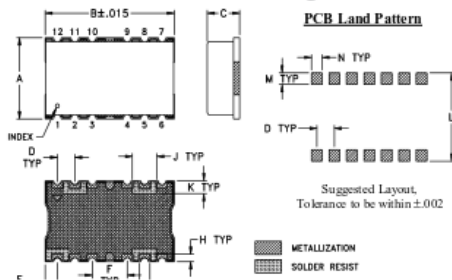
Permanent damage may occur if any of these limits are exceeded.

Pin Connections

IN	2
OUT	5
BIAS	8,12 [^]
GROUND	1,3,4,6,7,9,10,11

[^] proper operation is achieved with pins 8 or 12 or both connected to BIAS.

Outline Drawing



SPHSA-152+



CASE STYLE: JW1441

+RoHS Compliant

The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications

Features

- low insertion loss, 2.8 dB typ.
- good VSWR, 1.2:1 typ.
- wide phase shift, 360°
- aqueous washable

Applications

- cellular
- communication

Electrical Specifications at 25°C

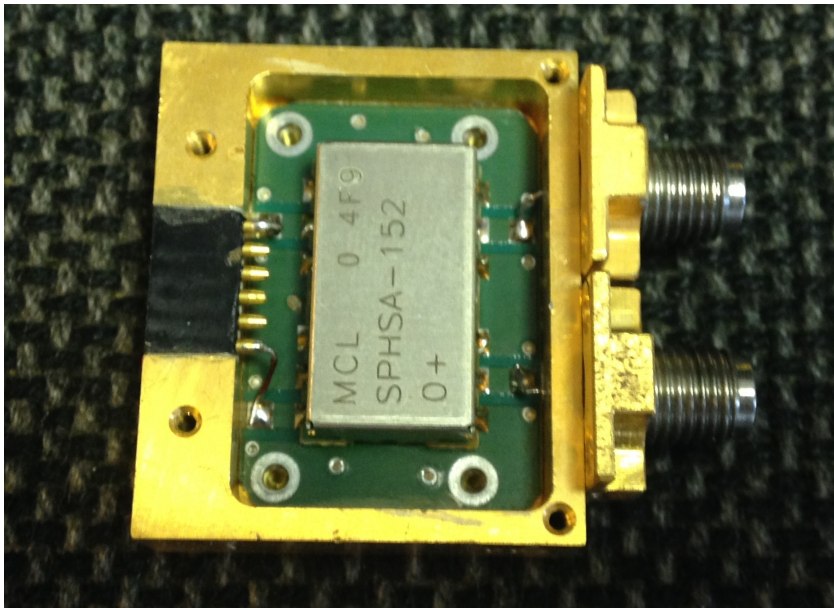
Parameter	Condition (MHz)	Min.	Typ.	Max.	Unit
Frequency Range		800		1500	MHz
Phase Range	800 - 1500	360	—	—	Degrees
Insertion Loss	800 - 1500	—	2.8	4.5	dB
Control Voltage	800 - 1500	—	0-15	—	V
Control Bandwidth	800 - 1500	—	DC-50	—	kHz
VSWR	800 - 1500	—	1.2	2.2	:1

DC input resistance at Control port: 2000 ohms typ.

Typical Performance Data

Control Voltage (V)	Phase Shift* (Degrees)			VSWR (:1)			Insertion Loss (dB)		
	800 MHz	1150 MHz	1500 MHz	800 MHz	1150 MHz	1500 MHz	800 MHz	1150 MHz	1500 MHz
0.0	0.01	0.00	0.01	1.22	1.20	1.16	3.07	2.19	2.17
1.0	43.39	20.01	10.59	1.25	1.16	1.13	3.41	2.33	2.21
2.0	91.98	43.59	22.68	1.15	1.10	1.09	3.58	2.50	2.26
3.0	146.94	73.94	38.05	1.27	1.03	1.08	3.69	2.72	2.35
4.0	201.09	112.39	57.90	1.69	1.06	1.13	3.85	2.99	2.49
5.0	247.66	158.14	83.54	1.91	1.15	1.24	3.72	3.22	2.73
6.0	286.91	209.47	117.36	1.78	1.17	1.40	3.23	3.27	3.09
7.0	320.04	262.81	161.73	1.47	1.11	1.54	2.65	3.10	3.56
8.0	345.88	310.38	213.44	1.22	1.07	1.50	2.25	2.87	3.86
9.0	363.68	345.50	261.60	1.11	1.14	1.31	2.04	2.68	3.79
10.0	375.33	369.18	299.37	1.14	1.19	1.15	1.94	2.54	3.58

Housing Design for Mini-Circuits Surface Mount Phase Shifter



Commercial Phase Shifter Candidates

1000-1500 MHz Voltage Controlled Phase Shifter

Model: ST-22-444A

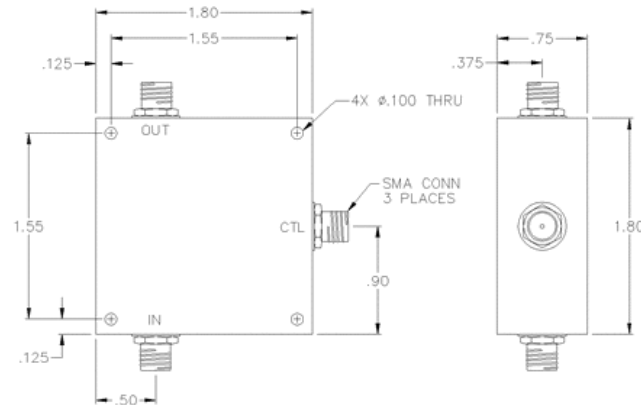
Pulsar phase shifter ST-22-444A covers the range 1000-1500 MHz, while our complete line of phase shifters cover frequency ranges up to 4.0 GHz. Any Pulsar model can be customized to suit your specific performance or package requirements at little to no extra cost. Pulsar is ISO-9001 certified and ITAR registered. RoHS compliance is standard, but non-compliance is available for military and other applications upon request.

[Specifications](#)

[Datasheet](#)

[Support](#)

[Request Quote](#)



Frequency Range (MHz)	Insertion Loss (dB) max.	Phase Shift (deg) min.	Control Voltage (Volts)	RF Input Power (dBm) max.	VSWR max.	P/N
1000-1500	4.0	360	0-10	0	1.70:1	ST-22-444A

Test Plan

Bench Tests (500-2000 MHz)

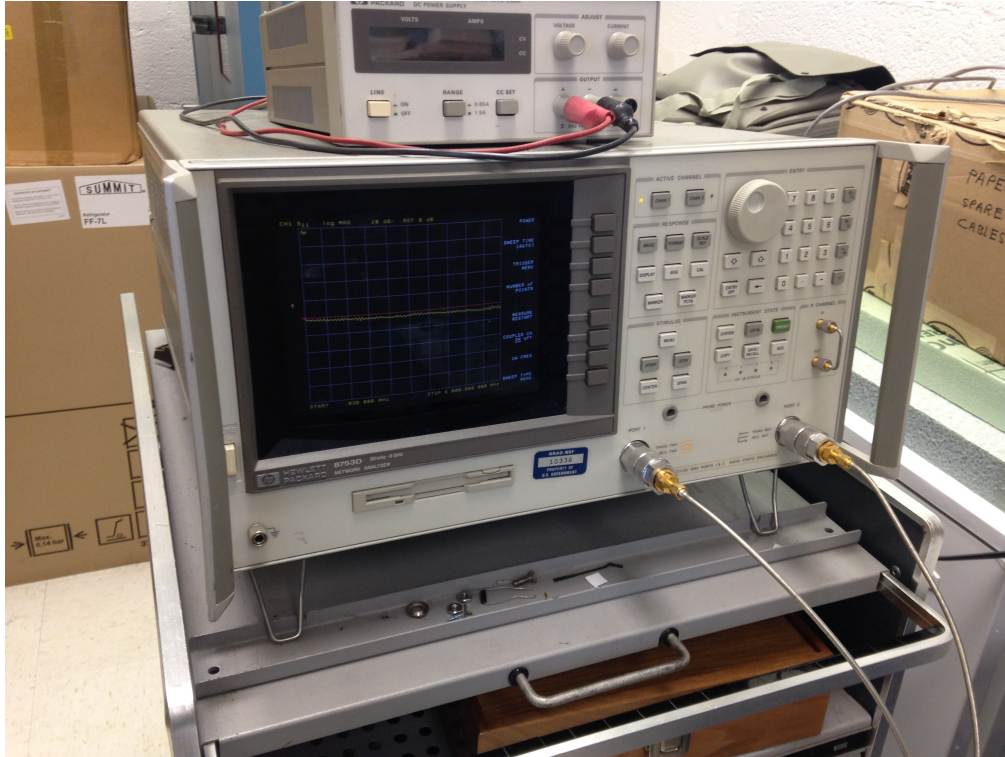
- S-Parameter measurements of phase shifter at 300 K on bench
- Estimate equivalent circuit model vs. DC bias

Cryogenic Tests (500-2000 MHz)

- S-Parameter measurements at 300 K and 15 K in Dewar
- De-embed Dewar transmission lines
- Estimate equivalent circuit model vs. DC bias



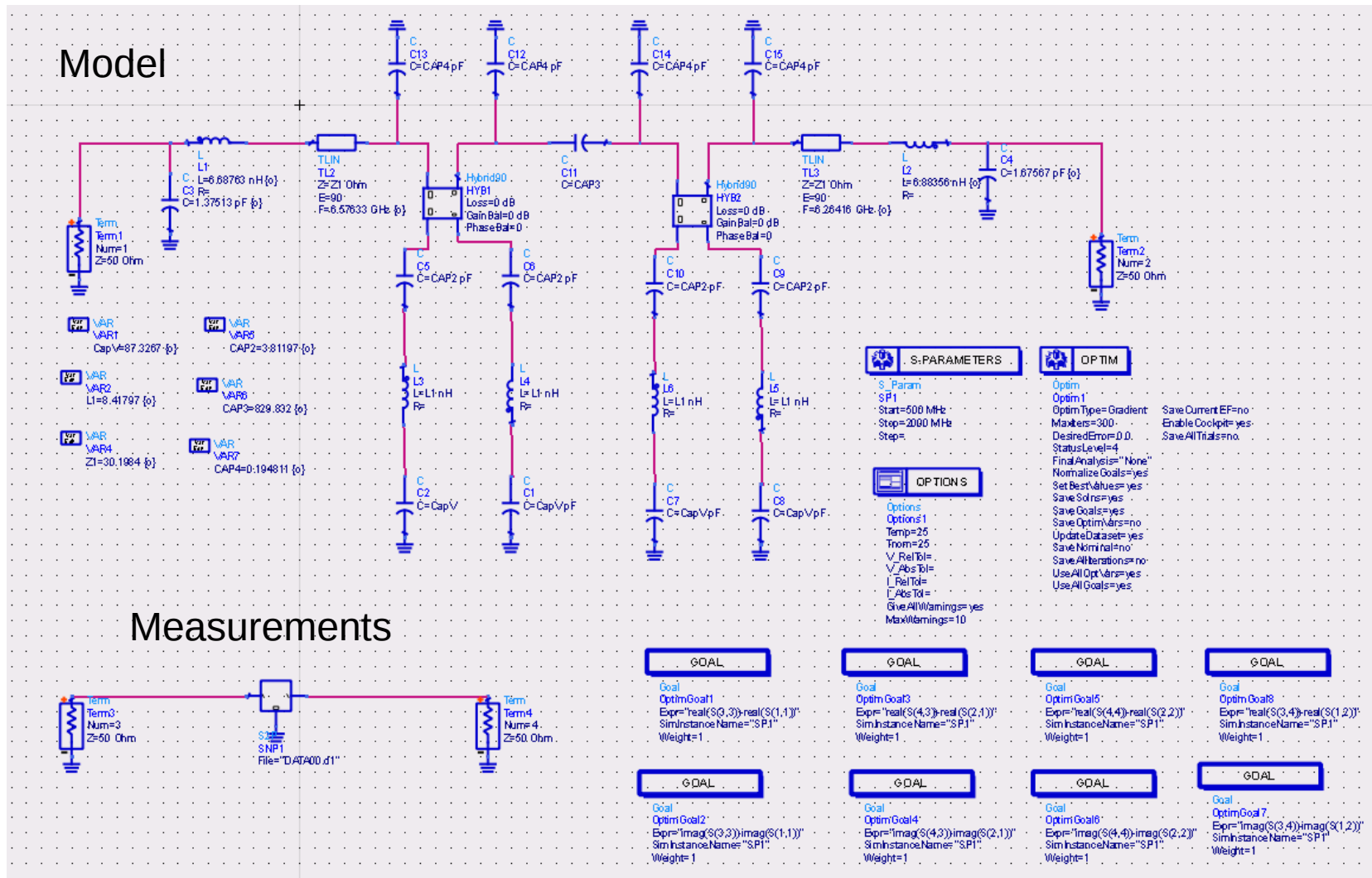
Bench Tests using VNA



Measure 2-port complex
S-Parameters vs. bias voltage
At 1 Volt increments

Series of S-parameter files

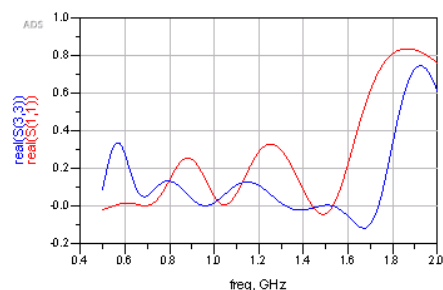
Model Fitting using Keysight ADS



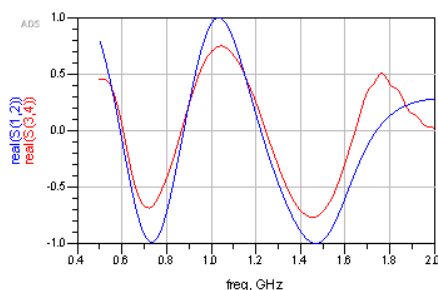
Model Fitting using Keysight ADS

S-Parameters

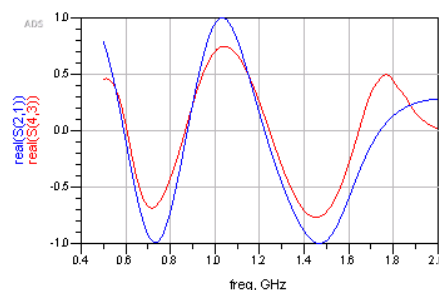
Real S11



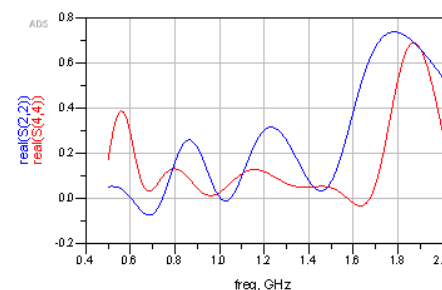
S12



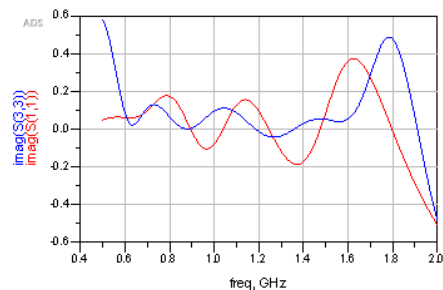
S21



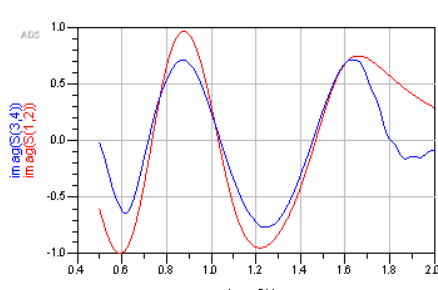
S22



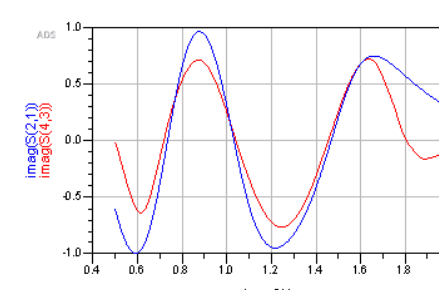
Imaginary S11



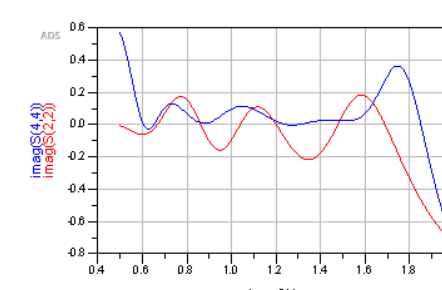
S12



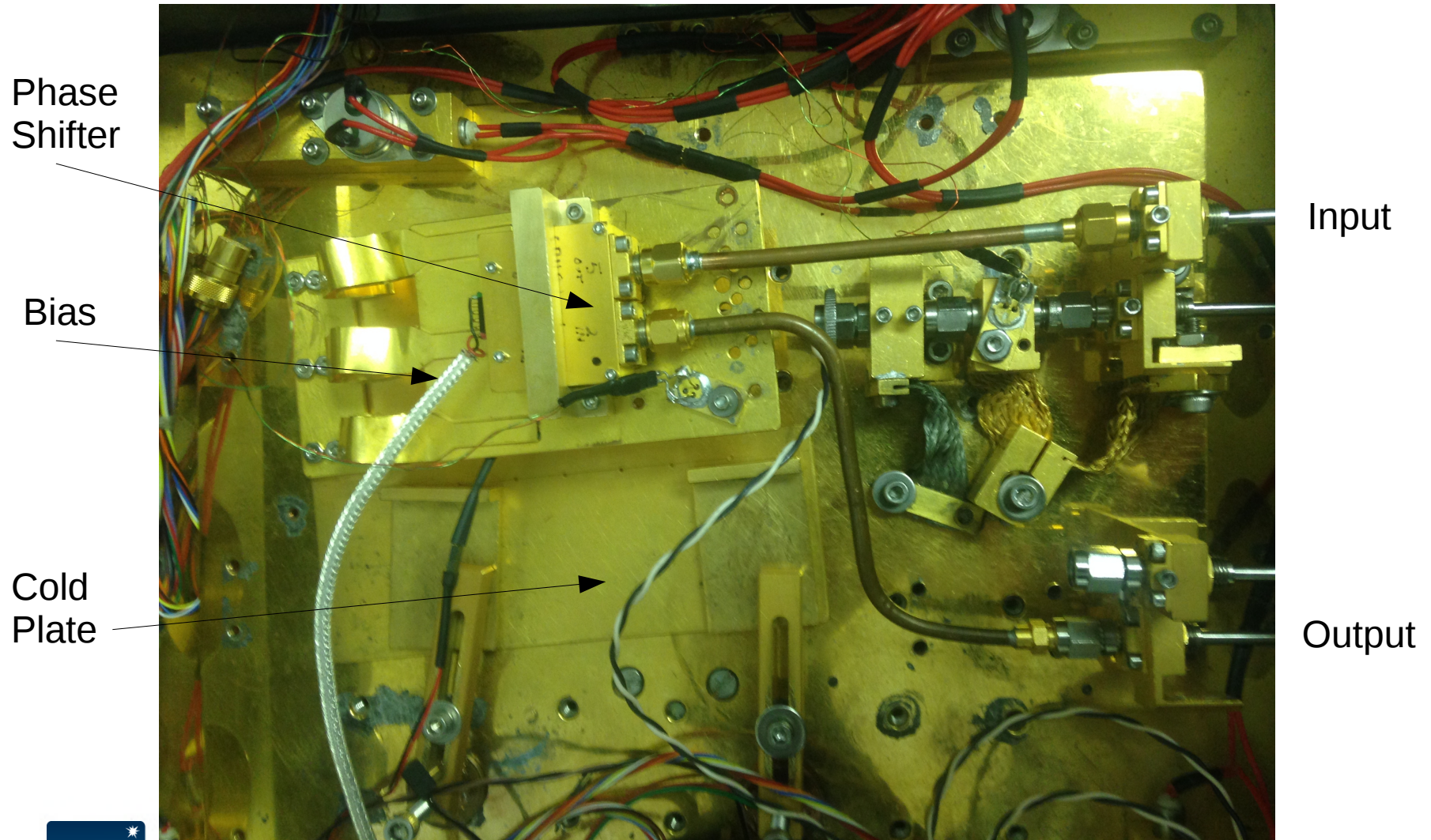
S21



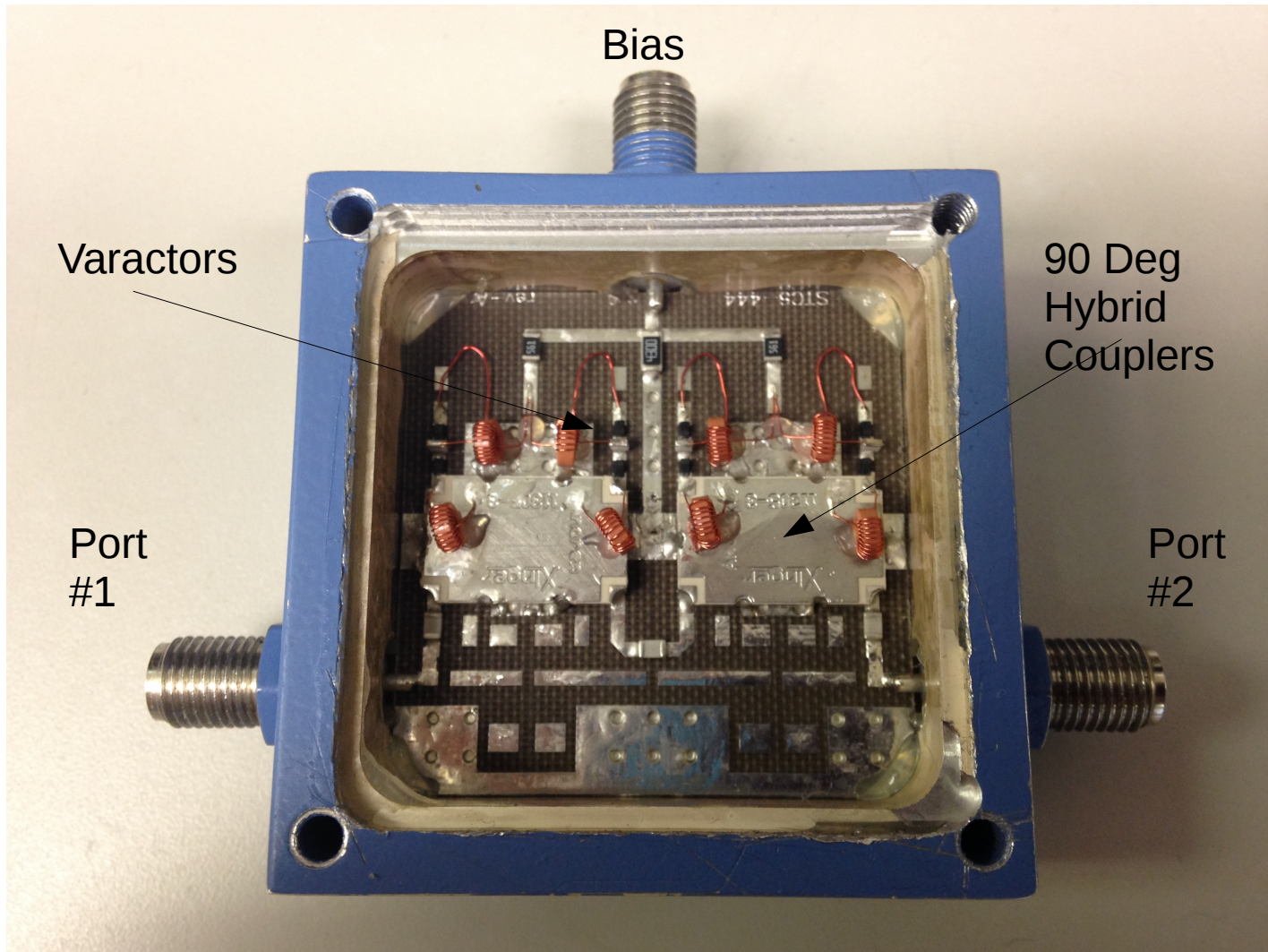
S22



Cryogenic Cooling



Inside a Commercial Phase Shifter



Inside a Commercial Phase Shifter

Anaren

Model 11305-3

Rev. A

Xinger®

Hybrid Couplers 3 dB, 90°



Description

The 11305-3 is a low profile 3dB hybrid coupler in an easy to use surface mount package covering 1.0 to 2.0 GHz. The 11305-3 is ideal for balanced amplifiers and signal distribution and can be used in most high power designs. Parts have been subjected to rigorous qualification testing and units are 100% tested. They are manufactured using materials with x and y thermal expansion coefficients compatible with common substrates such as FR4, G-10 and polyamide.

Features:

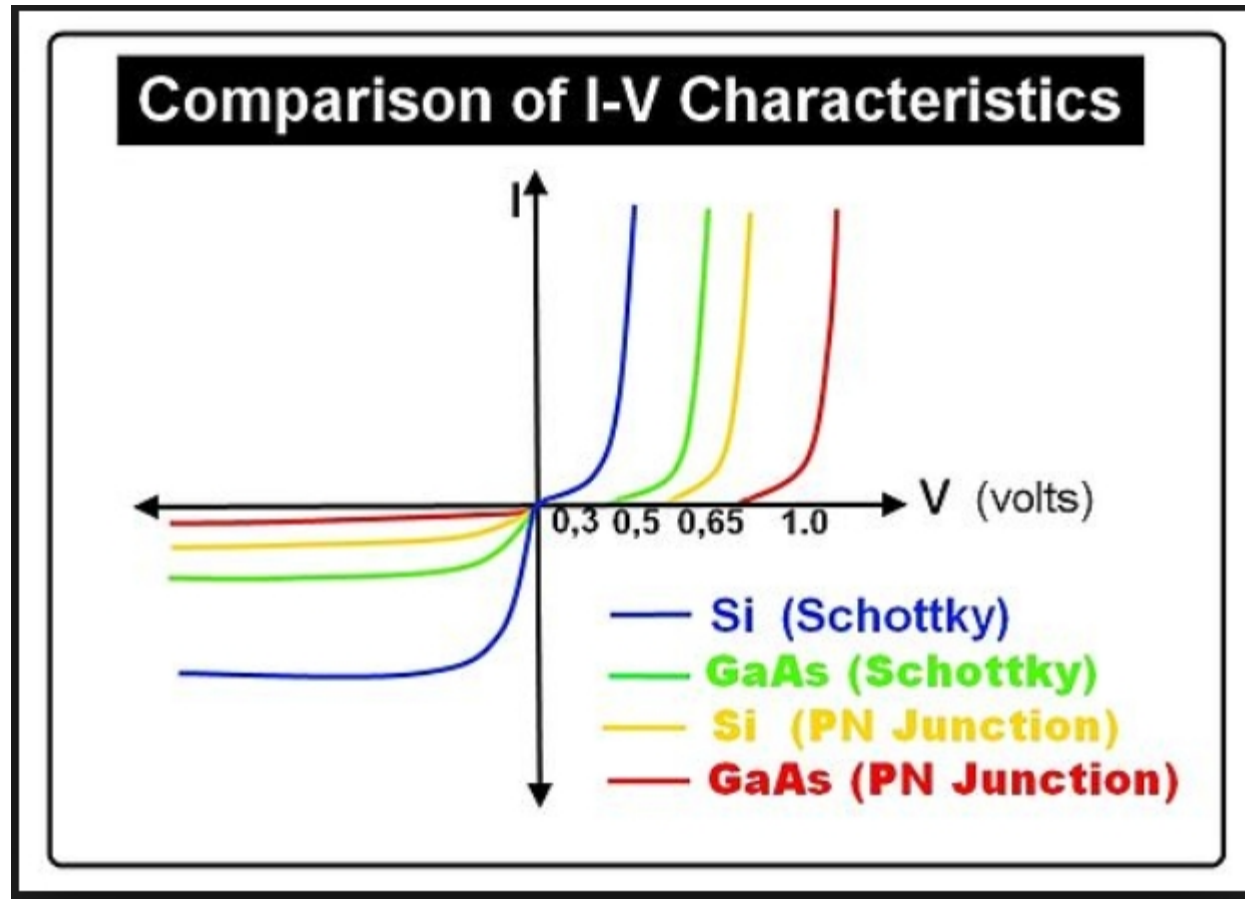
- 1.0 – 2.0 GHz
- Low Loss
- High Isolation
- 90° Quadrature
- Surface Mountable
- Tape And Reel
- Convenient Package
- 100% Tested

ELECTRICAL SPECIFICATIONS**

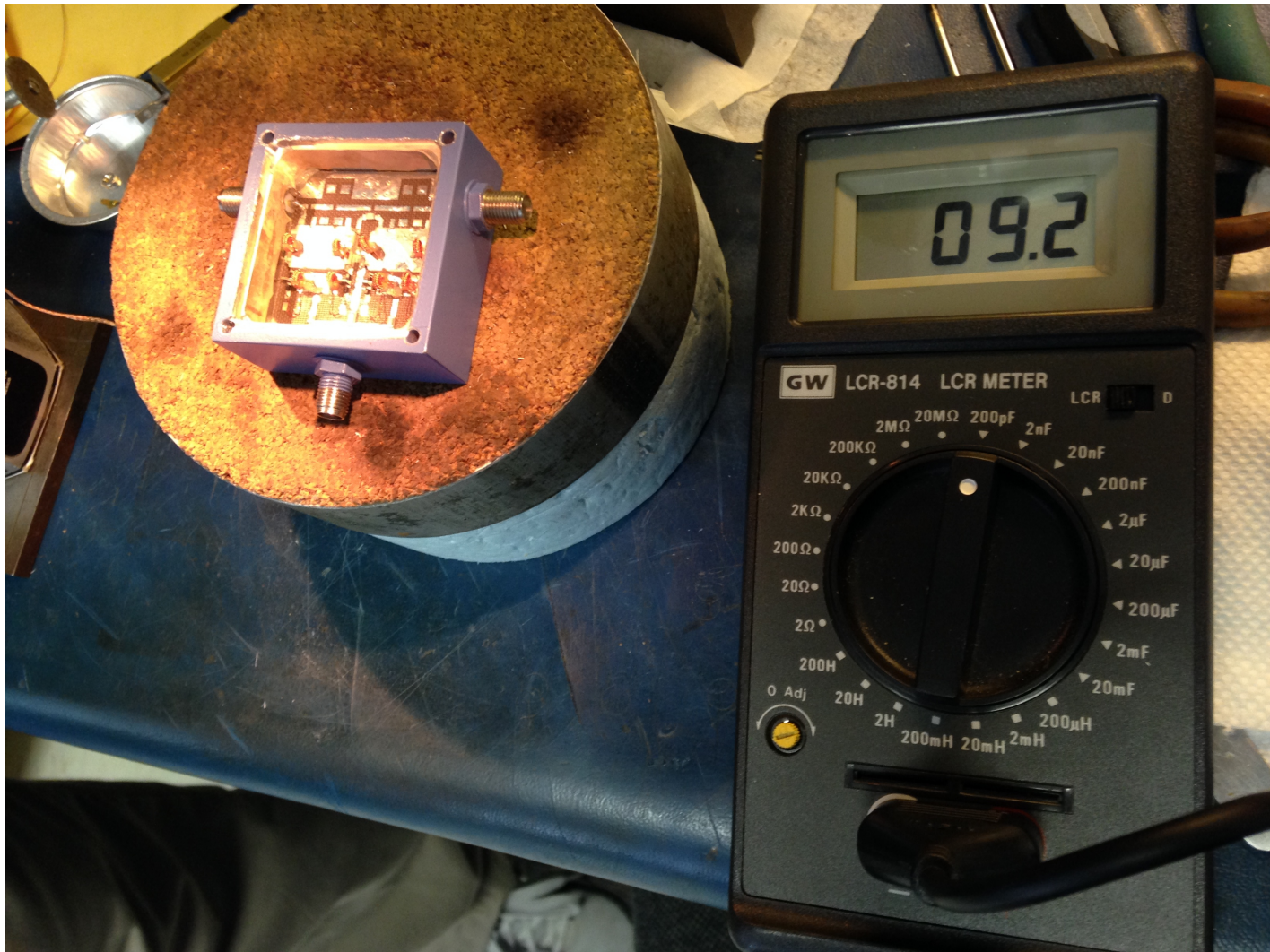
Frequency	Isolation	Insertion Loss	VSWR		
GHz	dB Min	dB Max	Max:1		
1.0 – 2.0	20	0.45	1.30		
Amplitude Balance	Phase Balance	Power	ΘJC	Operating Temp.	
dB Max	Degrees	Ave. CW Watts	°C/Watt	°C	
± 0.55	± 3	60	18.6	-55 to +85	

**Specification based on performance of unit properly installed on microstrip printed circuit boards with 50 Ω nominal impedance. Specifications subject to change without notice.

Current-Voltage Measurements

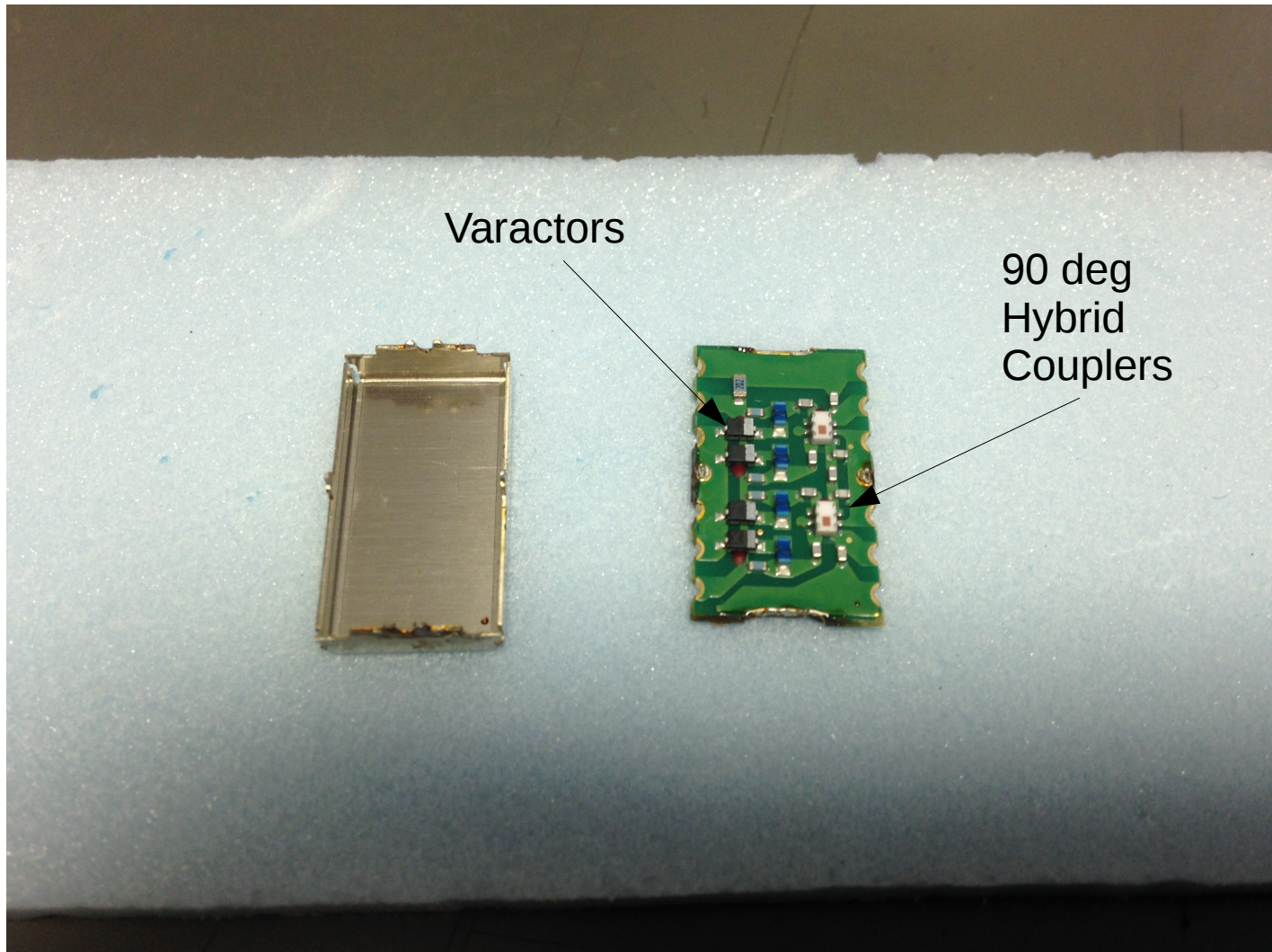


Capacitance Measurements



Inside a Commercial Phase Shifter

Mini-Circuits



GaAs Varactor Replacement



GaAs Varactor Diodes

Abrupt Junction

MV20001 – MV21010

Features

- High Q Values for Higher Frequency Performance
- Constant Gamma Design
- Low Reverse Current
- Available as Chip or Packaged Diodes
- Available in Chip-on-Board Packaging
- Custom Designs Available

Applications

- VCOs
- Phase-Locked Oscillators
- High Q Tunable Filters
- Phase Shifters
- Pre-Selectors

Maximum Ratings

Reverse Voltage	Breakdown Voltage
Forward Current	50 mA @ 25°C
Incident Power	+20 dBm @ 25°C
Operating Temperature	-55°C to +175°C
Storage Temperature	-55°C to +200°C



Description

Microsemi's GaAs abrupt junction varactors are fabricated from epitaxial layers grown at Microsemi using Chemical Vapor Deposition. The layers are processed using proprietary techniques resulting in a high Q factor and very repeatable tuning curves. The diodes are available in a variety of microwave ceramic packages or chips for operation from UHF to millimeter wave frequencies.

Summary

- Basic test and modeling procedures have been defined
- Initial tests reveal that silicon PN junction varactor are used
- Replacement GaAs Varactors are currently being sought