Design Comparison

Selection of OMT Design for the EVLA X-band Receiver

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Senior Engineer

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

What's Next…

- We have 4 possible OMT designs to chose from…
- These need to be evaluated & compared with the following in mind:
  - Performance
  - Cost
  - Schedule Impact
  - Any outstanding technical Issues
- These aspects also have to be properly weighted
  - If you have 2 receiver designs and one is twice as sensitive as the other but costs twice as much and takes twice as long, is it still worth it?
  - This is why the EVLA Program Manager gets paid the Big Buck$…

EVLA X-Band OMT Specifications

- Performance Specifications (based on higher frequency Wollack OMT designs):

  - Return Loss < -15 dB (required)
  - < -20 dB (desired)
  - Insertion Loss < -0.2 dB
  - Isolation < -35 dB

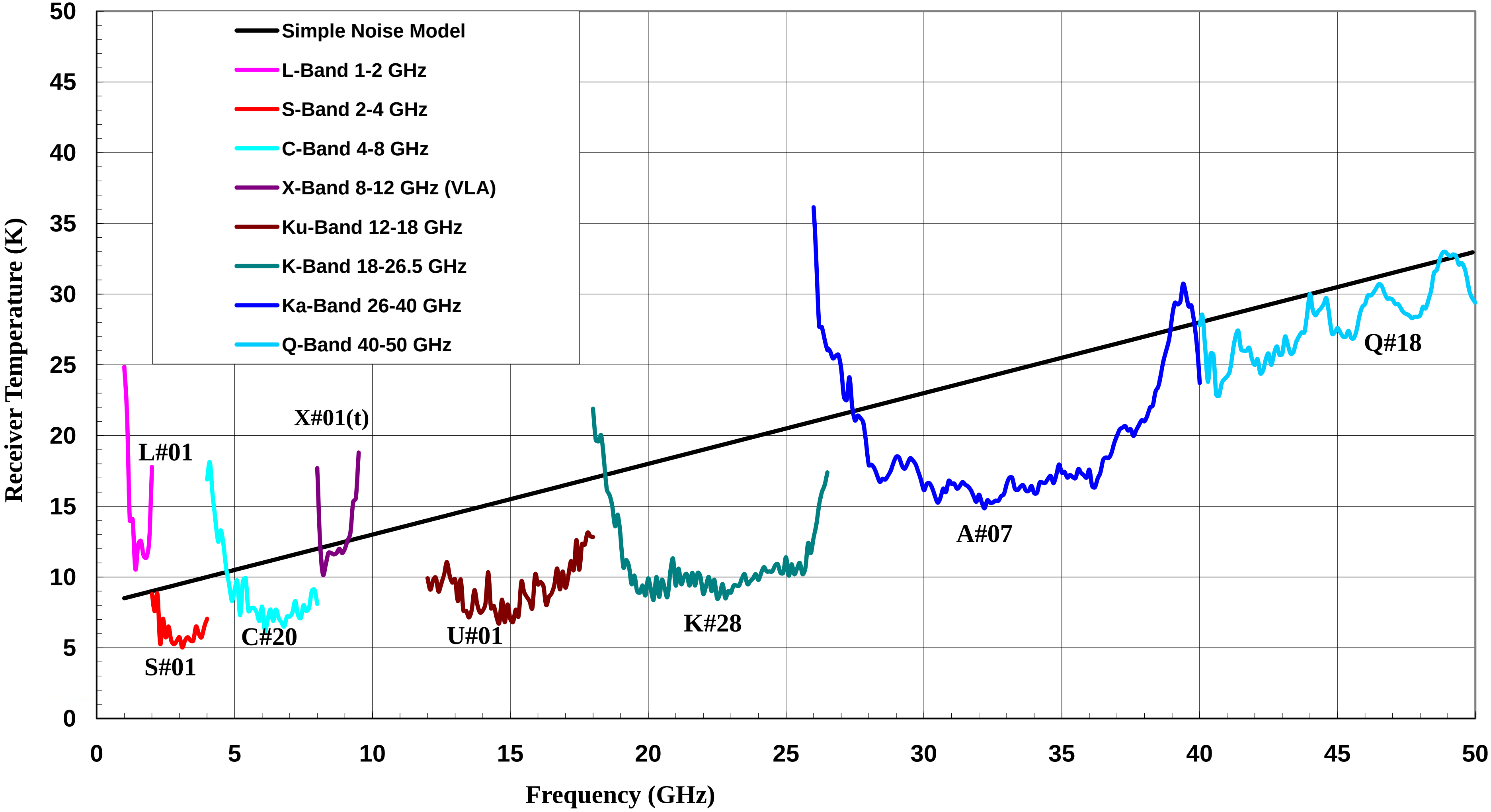
- Obviously any OMT that exceeds these specs gets brownie points

VLA/EVLA

(29 July 2009)

T_{Rx} versus Frequency

EVLA Project Book - T_{Rx} Requirements (Band Center)								
Band	L	S	C	X	Ku	K	Ka	Q
T_{Rx}	14	15	16	20	25	34	40	48



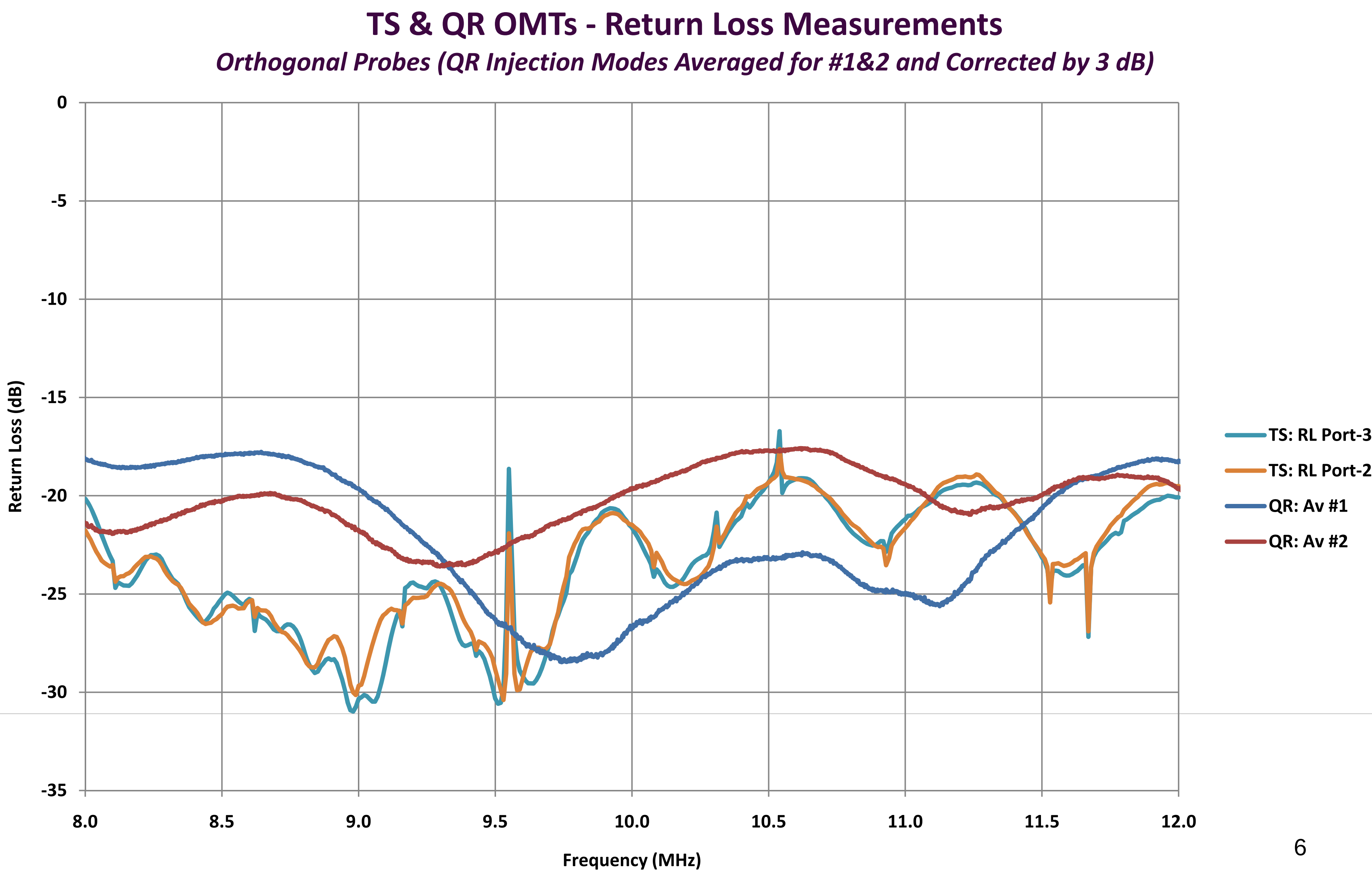
Simple Noise Model : $T_{Rx} = m \cdot F + b$; $m = 0.5°K/GHz$; $b = 8°K$

Waveguide OMT Comparison

- Turnstile & Offset Quadridge designs give better RF performance than a Planar OMT but at the cost of a large Dewar package
- Length of Waveguide Circular Polarizers:
  - Turnstile OMT based Polarizer Length:
    - Circular to square transition = 2.3"
    - Phase Shifter = 8.1"
    - 45° Twist = 3.5”
    - OMT = 2.7”
    - Dimensions of RF tree L x W = 16.6“ x 9.3”
  - Quadridge OMT based Polarizer Length:
    - Circular to square transition = 2.3"
    - Phase Shifter = 8.1“
    - OMT = 6.1”
    - Dimensions of RF tree L x W = 16.5“ x 2.0”
  - Both designs too big to fit inside the existing VLA X-Band Dewar, which was the design constraint leading to the Planar OMT development effort

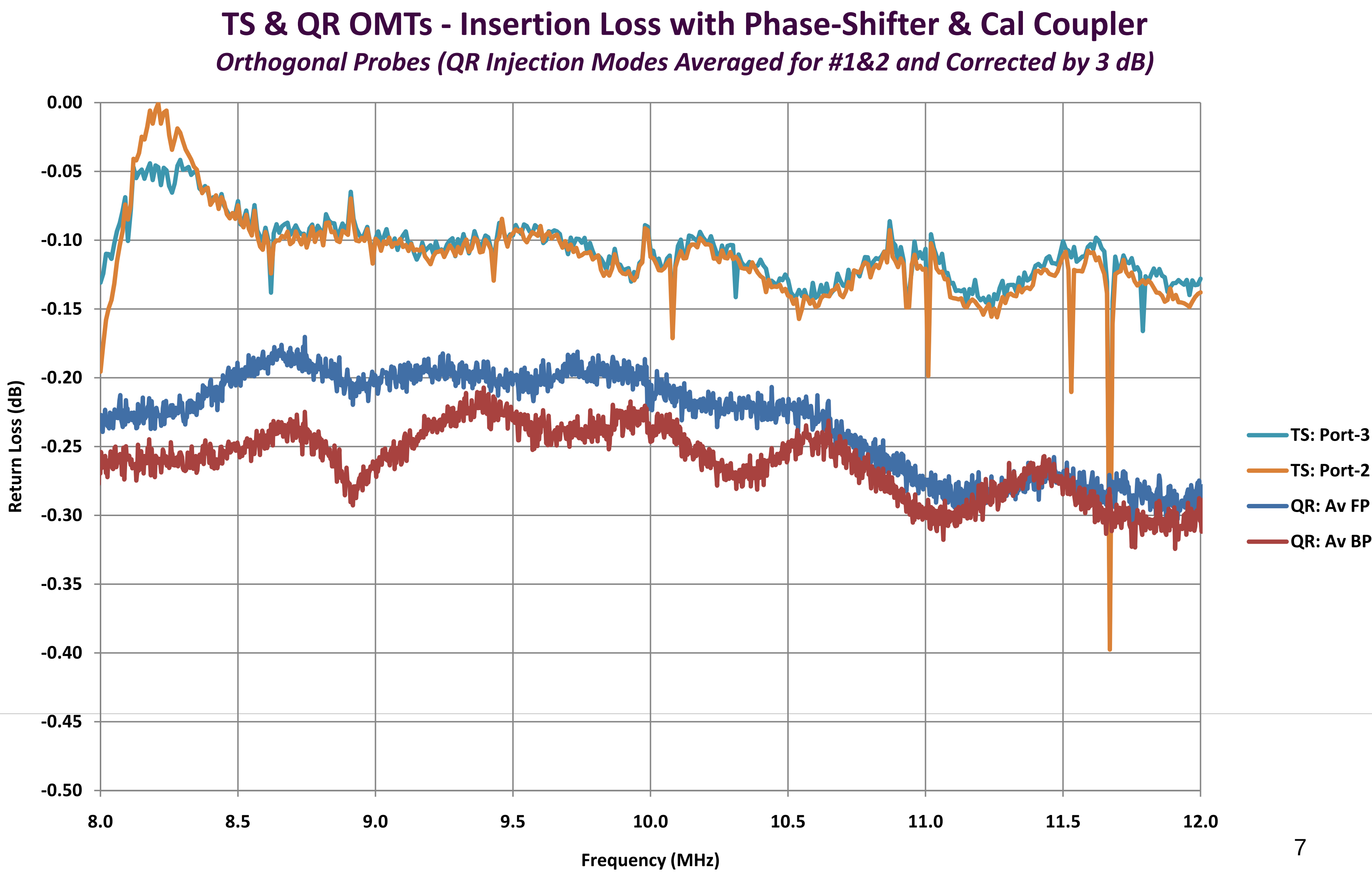
Waveguide OMT Return Loss
Turnstile vs. Offset Quadridge

EVLA



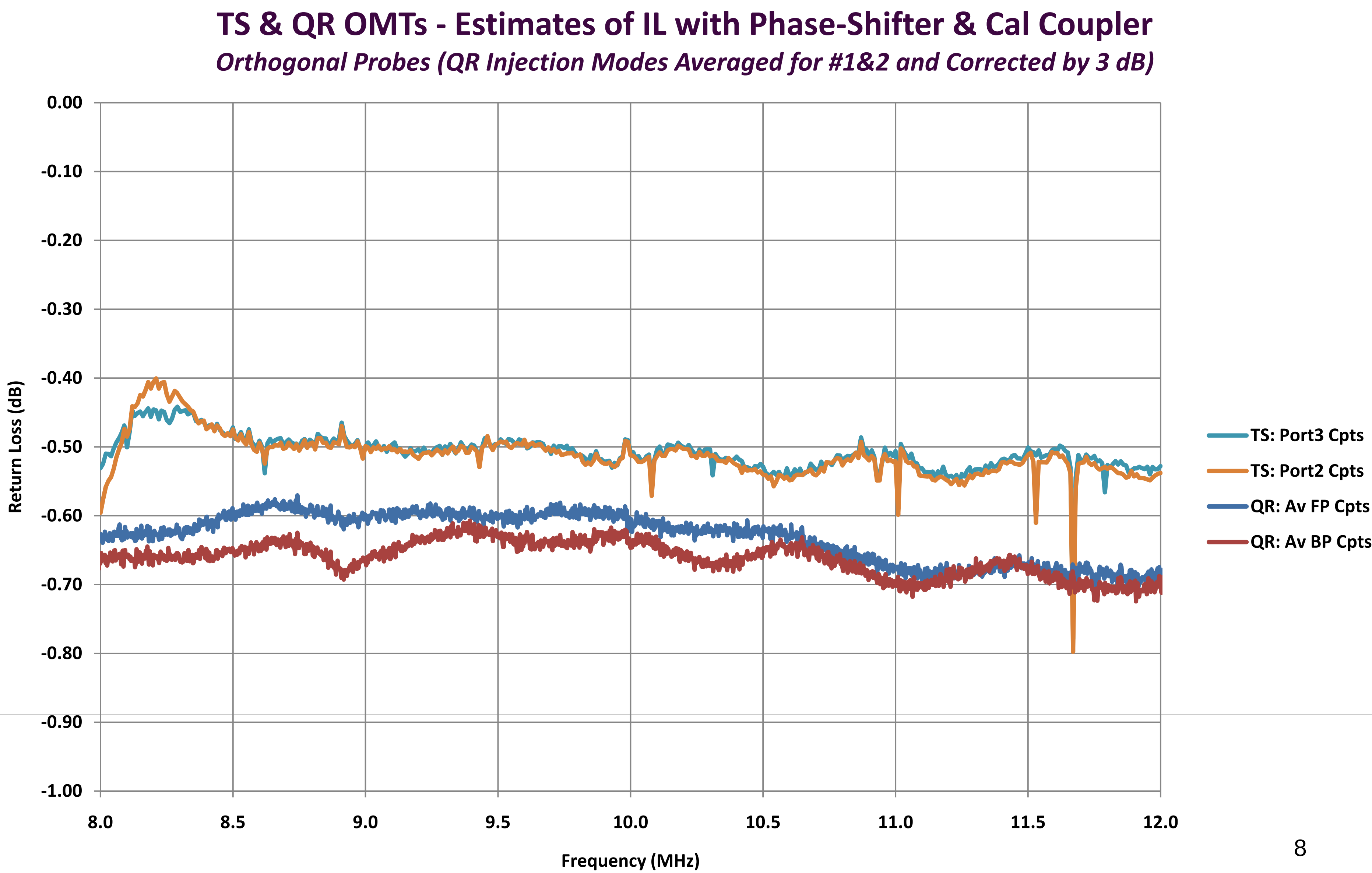
Waveguide OMT Insertion Loss

Turnstile vs. Offset Quadridge



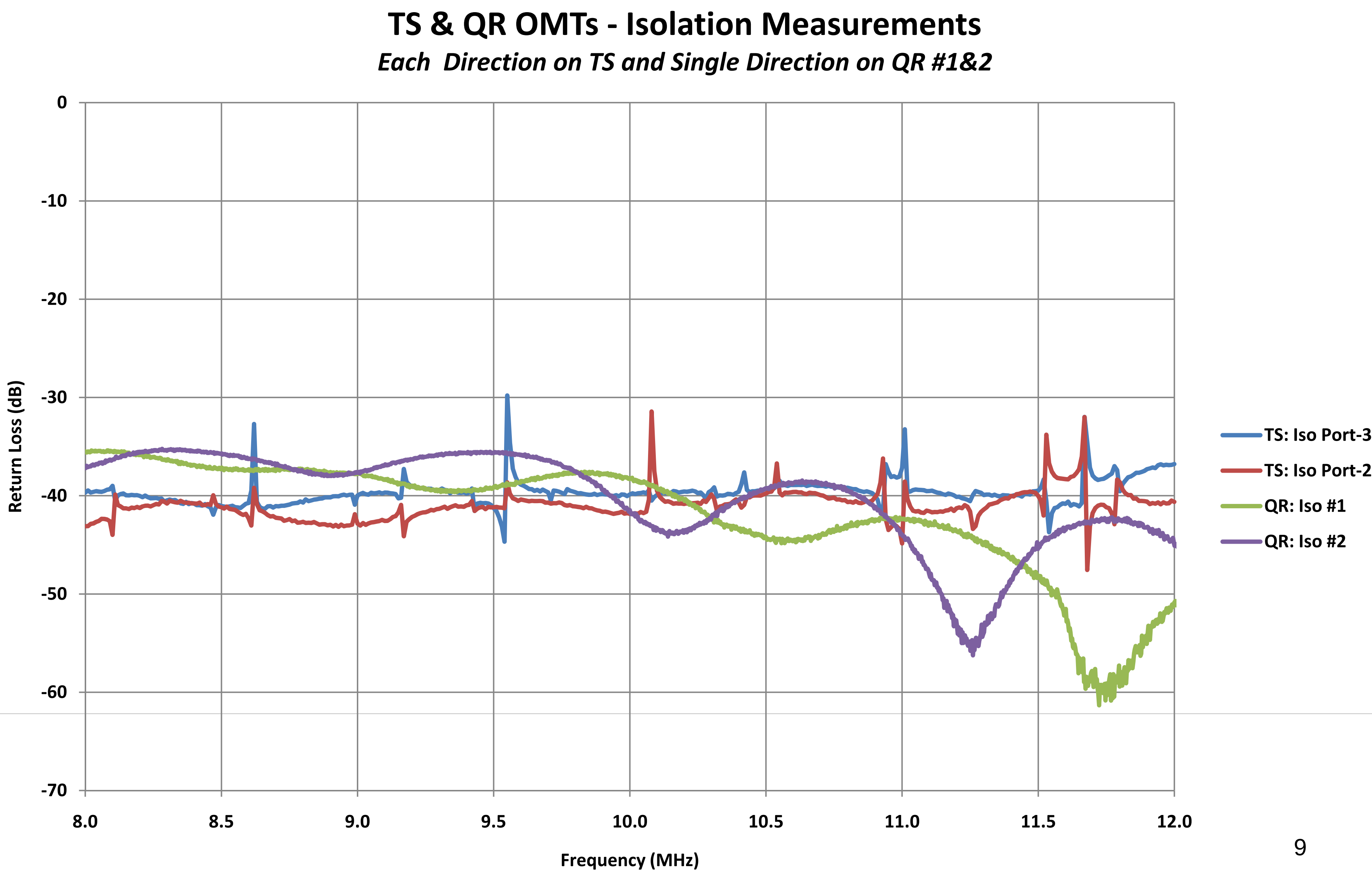
Waveguide OMT Insertion Loss

Turnstile vs. Offset Quadridge



Waveguide OMT Return Loss

Turnstile vs. Offset Quadridge



Turnstile vs. Offset Quadridge

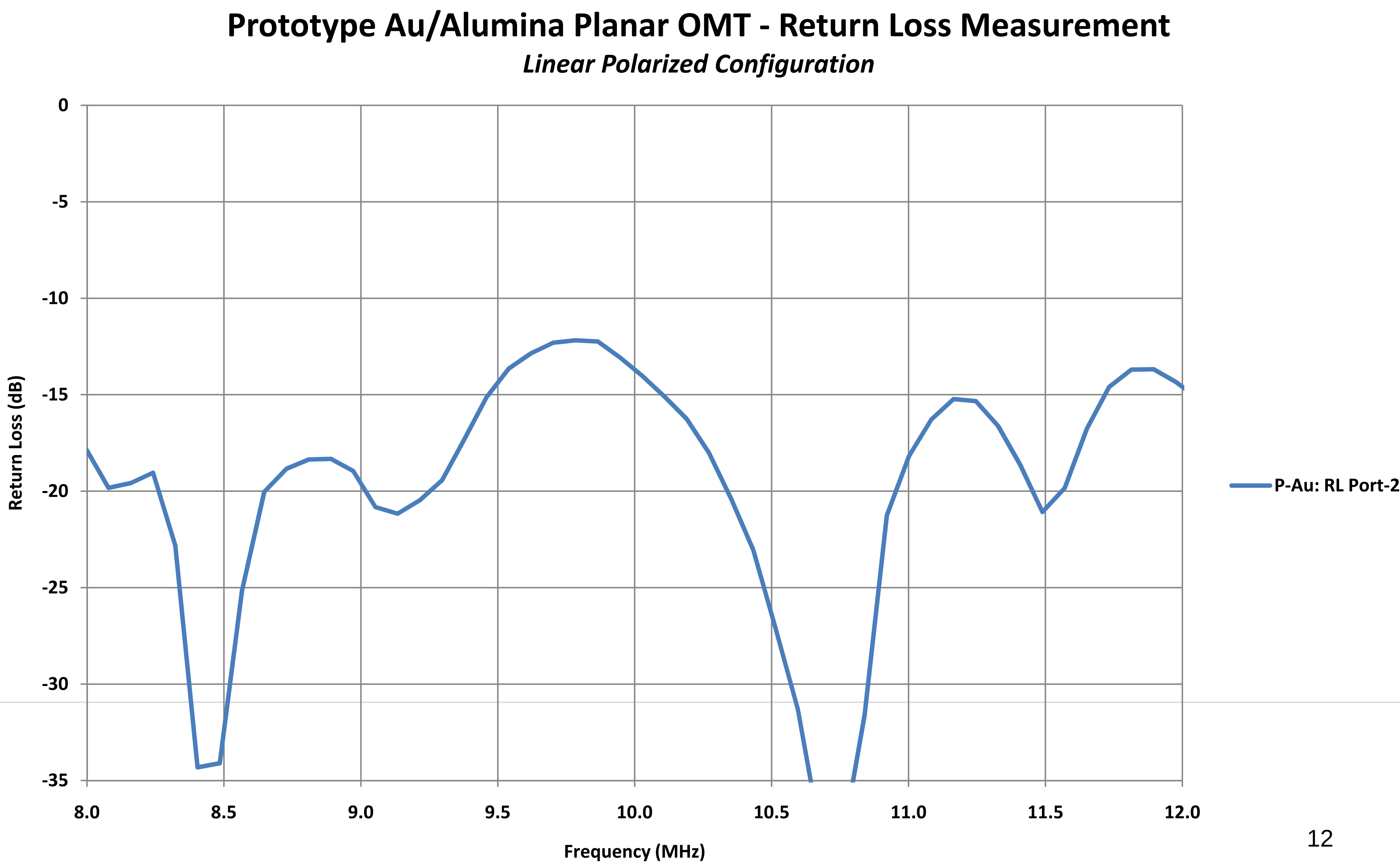
- Both OMTs have very similar Return Loss and Isolation performance
- Turnstile OMT has slightly better Insertion Loss (0.15 vs 0.30 dB) because it is inherently a waveguide device
  - This might allow for the option of maintaining a lower loss waveguide path all the way up to and including the LNA input
    - Similar to the design of the EVLA Ku-Band receiver which uses a Srikanth Phase-Shifter + Wollack OMT
    - Requires using a waveguide cross-guide coupler (custom/commercial)
    - Requires a cryogenic junction isolator (0.2 dB lower loss than Coaxial Iso)
    - CDL will have to modify their 8-12 GHz LNAs so that a WR90 flange replaces the K-Connector input – Marian might enjoy the challenge!
    - The Turnstile OMT layout needs a slight redesign so that the waveguide outputs come out the top of the block rather than the bottom so the CC+Iso+LNA assemblies sit in the “dead space” around the Phase-Shifter
- Offset Quadridge has equivalent performance to the Turnstile if the latter has WR90-to-Coax adapters installed to provide SMA outputs

Planar OMT Development

- Work package for the design of an X-Band Planar OMT has been underway by Stennis for less than a year
- The effort to develop the successful EVLA Quadridge OMTs for L/S/C-Band took over 6 years and 4 different engineers (Lilie, Locke, Stennis and Coutts)
- Stennis had to investigate numerous design avenues & novel planar techniques for two OMT designs (Normal vs. Superconducting)
  - Design of dual thermal gap assemblies (300/50K & 50/15K)
  - Planar waveguide probes
  - Microstrip 180°and 90°Hybrids Couplers & 30 dB Directional Couplers
  - Gold on Alumina microstrip circuits
  - High Temperature (HTS) microstrip circuits
  - Modified old X-Band Dewar to perform full-up cryogenic system tests
- The current development phase is incomplete & should continue no matter what the X-OMT decision turns out to be as this design might eventually have a useful role to play (maybe a 3:1 BW for SKA)

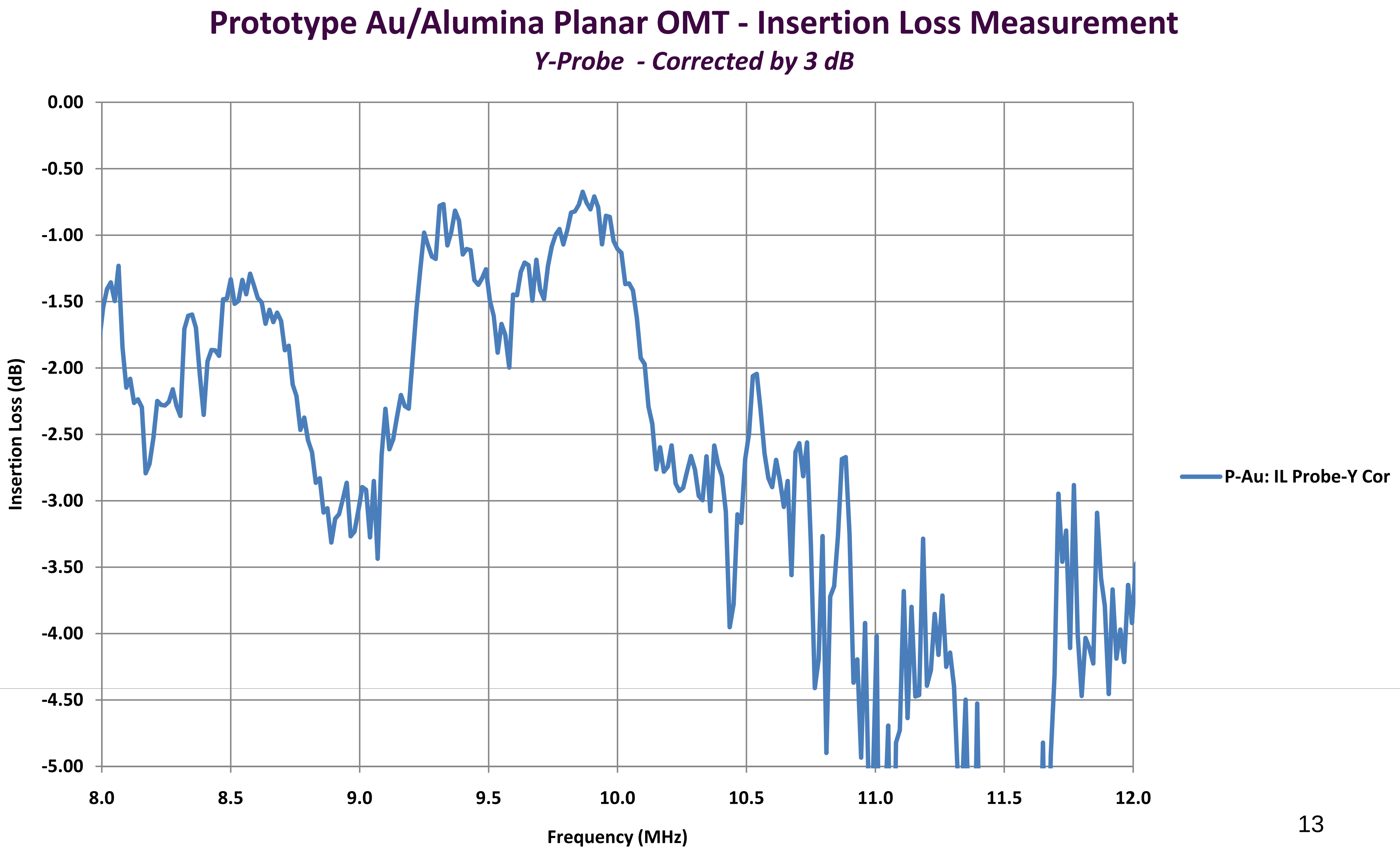
Planar OMT Return Loss

WG Probe & 180/90°Couplers Not Yet Optimized



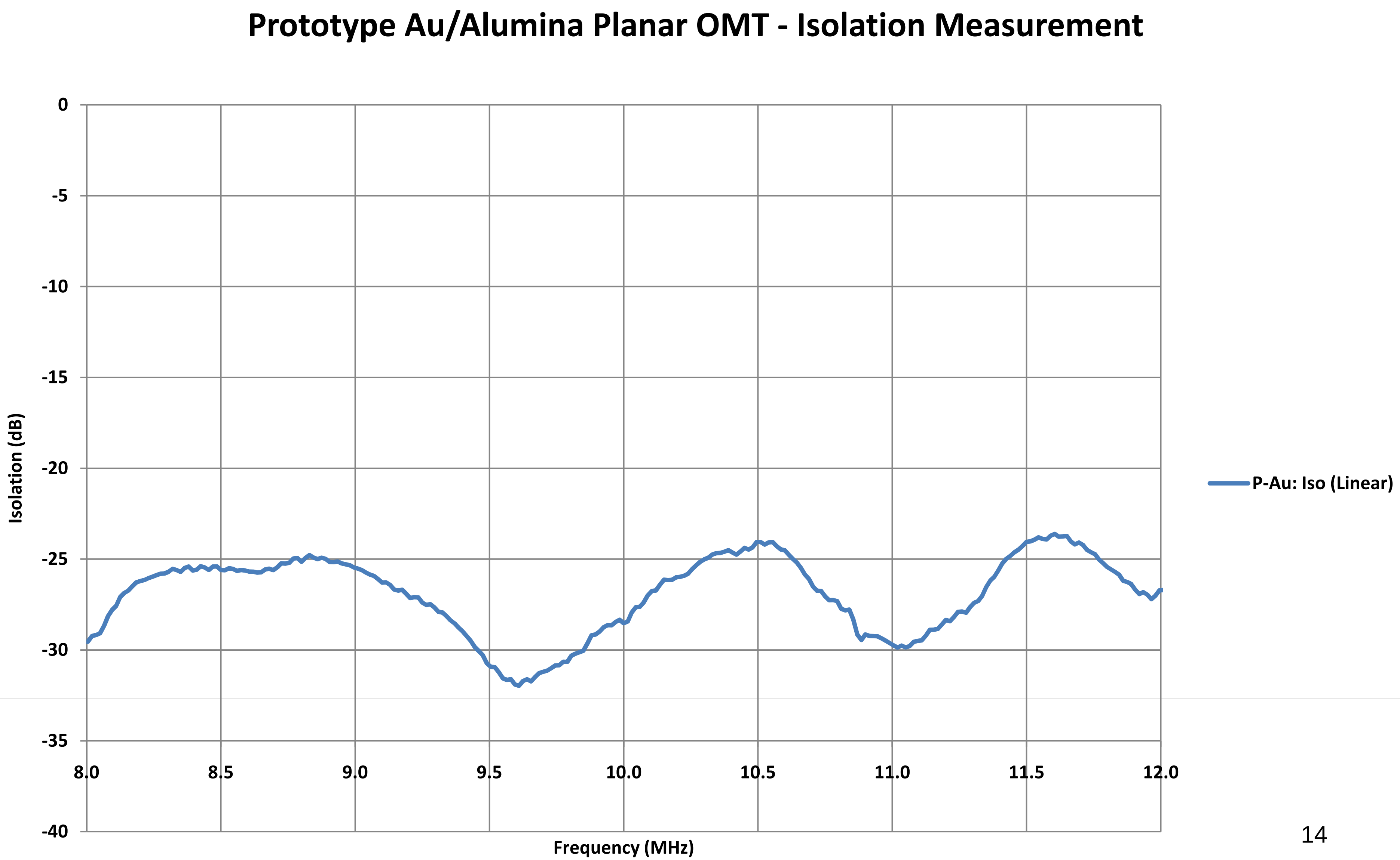
Planar OMT Insertion Loss

Problems with 50/15K Thermal Gap & Interconnects



Planar OMT Isolation

Problems with Microstrip Cross-overs and 90° Hybrids



T_{RX} Noise Model Estimates

- To compare the noise performance of the various OMTs, a noise model is used to estimate the Receiver Temperature based on
    - Insertion Loss measured for each OMT
    - Insertion Loss of the various other components (e.g., Phase-Shifter, Cal Coupler, Cryogenic Isolator, etc.)
    - Physical Temperature of all these components
  - Depending on the OMT, some components in the model are not needed and are excised from the noise calculations
  - An attempt is also made to predict the effect of cooling with Model 350 & Model 22 refrigerators
- No attempt is made to model reflections (i.e., Return Loss of the various components in the signal path) or changes in the IL as the component gets colder
- No attempt to predict the change in LNA noise temperature with slight changes in physical temperature
- Some of the estimated values may be incorrect but they will be equally wrong for all the OMT scenarios

Receiver Temperature Estimates

Best Case "Baseline" Scenario with Model 350

EVLA

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Baseline Estimates:							
- 15K Dewar (Model 350)							
- Minimal IL							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	12		-0.1	0.977	0.281	
	45 Deg Twist	12		-0.05	0.989	0.143	
	OMT	12		-0.1	0.977	0.288	
	Interconnect	12		-0.1	0.977	0.298	
	Cal Coupler (IL)	12		-0.1	0.977	0.305	
	Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Isolator	12		-0.3	0.933	0.957	
	LNA	5		35	3162.278	5.977	
	Stainless Steel Coax	156		-2	0.631	0.034	
	Coax Cable	300		-1	0.794	0.047	
	Isolator	300		-0.5	0.891	0.028	
	Filter (8-12 GHz)	300		-1	0.794	0.066	
	Post-Amp	229.6	2.5	25	316.228	0.245	
	Isolator	300		-0.5	0.891	0.000	10.70

Receiver Temperature Estimates

Turnstile OMT Waveguide Scenario with Model 350

EVLA

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Turnstile OMT Estimates:							
- Brand New Dewar							
- Model 350							
- Waveguide i/p to LNA							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	12		-0.1	0.977	0.281	
	45 Deg Twist	12		-0.05	0.989	0.143	
	OMT	12		-0.15	0.966	0.434	
	Waveguide Section	12		-0.1	0.977	0.301	
	WG Cal Coupler (IL)	12		-0.1	0.977	0.308	
	WG Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Waveguide Isolator	12		-0.3	0.933	0.969	
	LNA (WG i/p)	5		35	3162.278	6.046	
	Stainless Steel Coax	156		-2	0.631	0.035	
	Coax Cable	300		-1	0.794	0.047	
	Isolator	300		-0.5	0.891	0.028	
	Filter (8-12 GHz)	300		-1	0.794	0.066	
	Post-Amp	229.6	2.5	25	316.228	0.247	
	Isolator	300		-0.5	0.891	0.000	10.94

Receiver Temperature Estimates

EVLA

Turnstile OMT Coaxial Scenario with Model 350

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Turnstile OMT Estimates:							
- Brand New Dewar							
- Model 350							
- Waveguide i/p to LNA							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	12		-0.1	0.977	0.281	
	45 Deg Twist	12		-0.05	0.989	0.143	
	OMT	12		-0.15	0.966	0.434	
	Semi-Rigid Cable	12		-0.1	0.977	0.301	
	Coaxial Cal Coupler (IL)	12		-0.2	0.955	0.624	
	Coaxial Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	12		-0.5	0.891	1.691	
	LNA (Coaxial i/p)	5		35	3162.278	6.478	
	Stainless Steel Coax	156		-2	0.631	0.037	
	Coax Cable	300		-1	0.794	0.050	
	Isolator	300		-0.5	0.891	0.030	
	Filter (8-12 GHz)	300		-1	0.794	0.071	
	Post-Amp	229.6	2.5	25	316.228	0.265	
	Isolator	300		-0.5	0.891	0.000	12.44

Receiver Temperature Estimates

EVLA

Turnstile OMT Waveguide Scenario with Model 22

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Turnstile OMT Estimates:							
- Brand New Dewar							
- Model 22							
- Waveguide i/p to LNA							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	18		-0.1	0.977	0.422	
	45 Deg Twist	18		-0.05	0.989	0.215	
	OMT	18		-0.15	0.966	0.651	
	Waveguide Section	18		-0.1	0.977	0.452	
	WG Cal Coupler (IL)	18		-0.1	0.977	0.462	
	WG Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Waveguide Isolator	18		-0.3	0.933	1.453	
	LNA (WG i/p)	5		35	3162.278	6.046	
	Stainless Steel Coax	159		-2	0.631	0.036	
	Coax Cable	300		-1	0.794	0.047	
	Isolator	300		-0.5	0.891	0.028	
	Filter (8-12 GHz)	300		-1	0.794	0.066	
	Post-Amp	229.6	2.5	25	316.228	0.247	
	Isolator	300		-0.5	0.891	0.000	12.16

Receiver Temperature Estimates

EVLA

Turnstile OMT Coaxial Scenario with Model 22

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Turnstile OMT Estimates:							
- Brand New Dewar							
- Model 22							
- Coaxial i/p to LNA							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	18		-0.1	0.977	0.422	
	45 Deg Twist	18		-0.05	0.989	0.215	
	OMT	18		-0.15	0.966	0.651	
	Semi-rigid Cable	18		-0.1	0.977	0.452	
	Coaxial Cal Coupler (IL)	18		-0.2	0.955	0.936	
	Coaxial Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	18		-0.5	0.891	2.536	
	LNA (Coaxial i/p)	5		35	3162.278	6.478	
	Stainless Steel Coax	159		-2	0.631	0.038	
	Coax Cable	300		-1	0.794	0.050	
	Isolator	300		-0.5	0.891	0.030	
	Filter (8-12 GHz)	300		-1	0.794	0.071	
	Post-Amp	229.6	2.5	25	316.228	0.265	
	Isolator	300		-0.5	0.891	0.000	14.18

Receiver Temperature Estimates

Offset Quadridge OMT Coaxial Scenario with Model 350

EVLA

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Offset Quadridge Estimates:							
- Modified X-Band Dewar							
- Model 350							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	12		-0.1	0.977	0.281	
	~~45 Deg Twist~~	12		0	1.000	0.000	
	OMT	12		-0.3	0.933	0.883	
	Semi-rigid Cable	12		-0.1	0.977	0.308	
	Coaxial Cal Coupler (IL)	12		-0.2	0.955	0.638	
	Coaxial Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	12		-0.5	0.891	1.730	
	LNA (Coaxial i/p)	5		35	3162.278	6.629	
	Stainless Steel Semi-rigid	156		-2	0.631	0.038	
	Coax Cable	300		-1	0.794	0.052	
	Isolator	300		-0.5	0.891	0.031	
	Filter (8-12 GHz)	300		-1	0.794	0.073	
	Post-Amp	229.6	2.5	25	316.228	0.271	
	Isolator	300		-0.5	0.891	0.000	12.97

Receiver Temperature Estimates

Offset Quadridge OMT Coaxial Scenario with Model 22

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Offset Quadridge Estimates:							
- Modified X-Band Dewar							
- Model 22							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	18		-0.1	0.977	0.422	
	~~45 Deg Twist~~	18		0	1.000	0.000	
	OMT	18		-0.3	0.933	1.325	
	Semi-rigid Cable	18		-0.1	0.977	0.462	
	Coaxial Cal Coupler (IL)	18		-0.2	0.955	0.957	
	Coaxial Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	18		-0.5	0.891	2.595	
	LNA (Coaxial i/p)	5		35	3162.278	6.629	
	Stainless Steel Semi-rigid	159		-2	0.631	0.039	
	Coax Cable	300		-1	0.794	0.052	
	Isolator	300		-0.5	0.891	0.031	
	Filter (8-12 GHz)	300		-1	0.794	0.073	
	Post-Amp	229.6	2.5	25	316.228	0.271	
	Isolator	300		-0.5	0.891	0.000	14.89

Receiver Temperature Estimates

HTS Planar OMT Scenario with Model 350

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
HTS Planar OMT Estimate							
- Reuse most of X-Band Dewar							
- Model 350							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	~~Phase Shifter~~	10		0	1.000	0.000	
	~~45 Deg Twist~~	10		0	1.000	0.000	
	OMT + Hybrid + Cal Coupler	10		-1	0.794	2.604	
	Semi-rigid Cable	10		-0.1	0.977	0.295	
	~~Cal Coupler (IL)~~	10		0	1.000	0.000	
	Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	10		-0.5	0.891	1.581	
	LNA (Coaxial i/p)	5		35	3162.278	7.269	
	Stainless Steel Semi-rigid	155		-2	0.631	0.042	
	Coax Cable	300		-1	0.794	0.057	
	Isolator	300		-0.5	0.891	0.034	
	Filter (8-12 GHz)	300		-1	0.794	0.080	
	Post-Amp	229.6	2.5	25	316.228	0.297	
	Isolator	300		-0.5	0.891	0.000	14.29

Receiver Temperature Estimates

EVLA

HTS Planar OMT Scenario with Model 22

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
HTS Planar OMT Estimate							
- Reuse most of X-Band Dewar							
- Model 22							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	~~Phase Shifter~~	15		0	1.000	0.000	
	~~45 Deg Twist~~	15		0	1.000	0.000	
	OMT + Hybrid + Cal Coupler	15		-1	0.794	3.906	
	Semi-rigid Cable	15		-0.1	0.977	0.442	
	~~Cal Coupler (IL)~~	15		0	1.000	0.000	
	Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	15		-0.5	0.891	2.371	
	LNA (Coaxial i/p)	5		35	3162.278	7.269	
	Stainless Steel Semi-rigid	157.5		-2	0.631	0.042	
	Coax Cable	300		-1	0.794	0.057	
	Isolator	300		-0.5	0.891	0.034	
	Filter (8-12 GHz)	300		-1	0.794	0.080	
	Post-Amp	229.6	2.5	25	316.228	0.297	
	Isolator	300		-0.5	0.891	0.000	16.53

Receiver Temperature Estimates

Gold/Alumina Planar OMT Scenario with Model 350

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Au/Alumina Planar OMT Estimate							
- Reuse most of X-Band Dewar							
- Model 350							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	~~Phase Shifter~~	10		0	1.000	0.000	
	~~45 Deg Twist~~	10		0	1.000	0.000	
	OMT + Hybrid + Cal Coupler	10		-2	0.631	5.883	
	Semi-rigid Cable	10		-0.1	0.977	0.371	
	~~Cal Coupler (IL)~~	10		0	1.000	0.000	
	Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	10		-0.5	0.891	1.990	
	LNA (Coaxial i/p)	5		35	3162.278	9.151	
	Stainless Steel Semi-rigid	155		-2	0.631	0.052	
	Coax Cable	300		-1	0.794	0.071	
	Isolator	300		-0.5	0.891	0.042	
	Filter (8-12 GHz)	300		-1	0.794	0.101	
	Post-Amp	229.6	2.5	25	316.228	0.375	
	Isolator	300		-0.5	0.891	0.000	20.07

Receiver Temperature Estimates

Gold/Alumina Planar OMT Scenario with Model 22

EVLA

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Au/Alumina Planar OMT Estimate							
- Reuse most of X-Band Dewar							
- Model 22							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	~~Phase Shifter~~	15		0	1.000	0.000	
	~~45 Deg Twist~~	15		0	1.000	0.000	
	OMT + Hybrid + Cal Coupler	15		-2	0.631	8.824	
	Semi-rigid Cable	15		-0.1	0.977	0.557	
	~~Cal Coupler (IL)~~	15		0	1.000	0.000	
	Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	15		-0.5	0.891	2.985	
	LNA (Coaxial i/p)	5		35	3162.278	9.151	
	Stainless Steel Semi-rigid	157.5		-2	0.631	0.053	
	Coax Cable	300		-1	0.794	0.071	
	Isolator	300		-0.5	0.891	0.042	
	Filter (8-12 GHz)	300		-1	0.794	0.101	
	Post-Amp	229.6	2.5	25	316.228	0.375	
	Isolator	300		-0.5	0.891	0.000	24.19

What about a “Hot” Polarizer ?

- For the Turnstile & Quadridge OMTs, if a Model 22 fridge is unable to cool the entire Circular Polarizer and as a result we also end up with all the components mounted on the 15K plate running warm, one option is to only cool the Circ-Sq + PS + OMT to 50K and have the CC + Iso + LNA properly chilled on the 15K stage
- This is similar to an EVLA L or S-Band receiver where the OMT is tied to the 50K stage
- This option is explored in the following noise models…

Receiver Temperature Estimates

Turnstile OMT Scenario cooled to 50K (Model 22)

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Turnstile OMT Estimates:							
- Brand New Dewar							
- Model 22							
- PS+OMT cooled to 50K							
- Coaxial i/p to LNA							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	50		-0.1	0.977	1.171	
	45 Deg Twist	50		-0.05	0.989	0.596	
	OMT	50		-0.15	0.966	1.808	
	Semi-rigid Cable	32.5		-0.1	0.977	0.816	
	Coaxial Cal Coupler (IL)	15		-0.2	0.955	0.780	
	Coaxial Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	15		-0.5	0.891	2.114	
	LNA (Coaxial i/p)	5		35	3162.278	6.478	
	Stainless Steel Coax	157.5		-2	0.631	0.038	
	Coax Cable	300		-1	0.794	0.050	
	Isolator	300		-0.5	0.891	0.030	
	Filter (8-12 GHz)	300		-1	0.794	0.071	
	Post-Amp	229.6	2.5	25	316.228	0.265	
	Isolator	300		-0.5	0.891	0.000	16.25

Receiver Temperature Estimates

Quadridge OMT Scenario cooled to 50 K (Model 22)

EVLA X-Band Rx		Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Tsys
(29 Sept 2009)		(K)	(dB)	(dB)	(linear)	(K)	(K)
Offset Quadridge Estimates:							
- Modified X-Band Dewar							
- Model 22							
Receiver	Weather Window	300		-0.01	0.998	0.692	
	Feed Horn	300		-0.01	0.998	0.693	
	Vacuum Window	300		-0.005	0.999	0.347	
	Phase Shifter	50		-0.1	0.977	1.171	
	~~45 Deg Twist~~	50		0	1.000	0.000	
	OMT	50		-0.3	0.933	3.680	
	Semi-rigid Cable	32.5		-0.1	0.977	0.835	
	Coaxial Cal Coupler (IL)	15		-0.2	0.955	0.798	
	Coaxial Cal Coupler (Branch)	300	-30	0	1.000	0.300	
	Coaxial Isolator	15		-0.5	0.891	2.163	
	LNA (Coaxial i/p)	5		35	3162.278	6.629	
	Stainless Steel Semi-rigid	157.5		-2	0.631	0.039	
	Coax Cable	300		-1	0.794	0.052	
	Isolator	300		-0.5	0.891	0.031	
	Filter (8-12 GHz)	300		-1	0.794	0.073	
	Post-Amp	229.6	2.5	25	316.228	0.271	
	Isolator	300		-0.5	0.891	0.000	17.77

T_{Rx} Summary

EVLA

Best, 2nd Best, 3rd Worst, Worst

	TS	QR	P-HTS	P-Au	Comment
Return Loss (dB)	-19	-18	-12 ?	-12 ?	As expected, WG OMTs better
Isolation (dB)	-36	-35	-19 ?	-19	P-Iso/Cross-Pol is worrisome
Insertion Loss (dB)	-0.15	-0.30	-1.0 ?	-2.0 ?	TS-Waveguide LNA
Estimated T_{Rx}(K) Model 350	10.9	13.0	14.3 ?	20.1 ?	TS in WG
	12.4	-	-	-	TS in Coax
Estimated T_{Rx}(K) Model 22	12.2	14.9	16.5 ?	24.2 ?	TS in WG
	14.2	-	-	-	TS in Coax
Estimated T_{Rx}(K), Model 22	15.7	17.2	-	-	OMT @ 50K

- Lowest noise solution is the Turnstile with a Model 350 fridge (10.9K)
- Best Model 22 solution (assuming a 350 is required to adequately cool a Turnstile) is the Quadridge OMT (14.2K)
- Best Planar OMT is the HTS solution (15.9K, assuming IL, RL & Iso problems resolved)

Cost Comparison

Best=1, 2, 3, 4=Worst

	TS	QR	P-HTS	P-Au	Comment
OMT Machining Difficulty	3	2	1	1	TS-Facing;
OMT Assembly Difficulty	1	2	4	3	P-Cpts/Bonding; P-HTS Testing
OMT Machining & Cpt Cost	860	550	3400	650	P-Add Machining Cost ($200?)
Cost Dewar	2/3 ?	2	1	1	TS&QR need new Dewar (350?)
Cost Infrastructure	4 ?	1	1	1	4th Compressor if 350

- The Planar OMT is the least difficult to machine. The Turnstile OMT is the most difficult due to the amount of precision facing required.
- Assembly cost of the Turnstile is the least. The Quadridge requires fine tuning of the coaxial probes. The Planar OMT assembly is much more extensive due to mounting of microstrip carriers and wire bonding.
- Cost of materials, components and machining is the least for the Quadridge and the highest for the HTS Planar OMT.
- Dewar costs are the least for the Planar OMT (reuses old X-Band Dewar) & highest for the Turnstile, especially if new Model 350 used.
- If Turnstile OMT requires a 350, a costly cascade occurs because of the need for a 4th Compressor (but could improve L-Band operations).

X-Band Deployment Schedule

- The production of new EVLA X-Band receivers is slated to begin in early 2010.
- To ensure that all new X-Band receivers are installed on the EVLA by the end of 2012, it will require fielding about 1 receiver per month through the end of the Project
- Any delay at the start will likely delay the completion since it will compete with manpower resources for the fabrication and testing of the new L, S, Ku-Band receivers
- While the machining man-hours is the least for Planar OMT (since it would reuse about 75% of the old VLA Dewar), it requires the most assembly effort from the FE Group (complicated mounting of sub-strates, wire bonding and testing/rework)
- While the Turnstile OMT requires a brand-new wider-diameter Dewar, it has recently been determined that the Quadridge OMT can reuse very little of the old VLA Dewar so both OMTs have similar manpower machining and assembly requirements
- Design of Dewar for Quadridge OMT is further along than that for a Turnstile OMT so this effort would have to be accelerated if it was chosen for the new design

Comparison Summary:

EVLA

Best=1, 2, 3, 4=Worst

	TS	QR	P-HTS	P-Au	Comment
Return Loss (dB)	1	2	3	3	As expected, WG OMTs better
Insertion Loss (dB)	1	2	3	4	TS-Waveguide LNA
Estimated T_{Rx} (K)	1	2	3	4	Model 350
Isolation (dB)	1	2	3	3	P-Iso/Cross-Pol is worrisome
Ellipticity	1	1	3	3	No Axial Ratios measured yet
OMT Repeatability	1	2	3	3	QR Probes; P-Interconnects ?
Short Term Reliability	1	1	3	3	Planar Wire Bonds ?
Long Term Survivability	1	2	4 ?	3	P-HTS Hermetic Sealing ?
OMT Machining Difficulty	3	2	1	1	TS-Facing
OMT Assembly Difficulty	1	2	4	3	P-Cpts/Bonding; P-HTS Testing
Cost OMT ($)	3	1	4	2	P-Cpt costs dominate
Cost Dewar	2/3 ?	2	1	1	TS&QR need new Dewar (350?)
Cost Infrastructure	4 ?	2	1	1	4^{th} Compressor if 350
Further R&D	2	1	4	3	Planar T-Gap, Iso, HTS Testing
Receiver Schedule	2	1	4	3	Dewars for WG; Planar R&D

Turnstile OMT Evaluation

- Pros:
  - Polarizer option with the highest sensitivity
  - OMT design is essentially complete (should be modified for output waveguide to come out the top)
  - Allows signal path in low-loss waveguide right up to LNA input
  - Polarization purity should be excellent (depends on amplitude and phase balance of Phase-Shifter)
- Cons:
  - Circulator polarizer is fat and long – requires a brand new Dewar design
  - Likely requires a Model 350 refrigerator for best cooling
  - If so, requires a 4th Compressor (would help L-Band cooling)
  - Requires CDL to modify 8-12 GHz LNA for waveguide input flange
  - Machining & assembly cost is slightly higher than the Quadridge OMT

Offset Quadridge OMT Evaluation

EVLA

- Pros:
  - Provides 2nd best polarizer sensitivity option
  - OMT design is essentially complete
  - Coolable with a Model 22 fridge
  - Polarization purity should be excellent (depends on amplitude and phase balance of Phase-Shifter)
  - Machining cost is slightly less than the Turnstile OMT
  - Small 2”x2” cross-section would make it perfect for a prime-focus focal plane array

- Cons:
  - Slightly higher Insertion Loss than the Turnstile OMT and no option to use lower-loss waveguide signal path up to LNA input
  - Circulator polarizer is long and narrow – requires a brand new Dewar design (reuse of any of the VLA X-Band Dewar is unlikely)
  - Model 22 cooling is close to the margin – Helium supply pressure is critical

Au/Alumina Planar OMT Evaluation

EVLA

- Pros:
  - Easily fits within the old VLA Dewar
  - Coolable with a Model 22 fridge
  - Integrated the Hybrid and Cal Couplers in a single block
  - Lowest cost for machining both the OMT and Receiver package
  - Lower Insertion loss might come from further optimization (perhaps half that of prototype)

- Cons:
  - Highest Insertion Loss and thus the least sensitive option (more development would likely cut the loss in half)
  - Cost of assembly is higher than the other OMTs
  - Polarization purity yet to be investigated (may require tuning of the amplitude and phase at the input to the 90°Hybrid)
  - More development effort required to optimize performance (less than a year to date so far to investigate this truly novel technique)

HTS Planar OMT Evaluation

EVLA

- Pros:
  - Ditto as for Au/Alumina version
  - Lower Insertion loss might come from further optimization, possibly competitive with the Quadridge OMT (perhaps as low as 0.6 dB)
- Cons:
  - Ditto as for Au/Alumina version
  - Robustness to moisture could be a serious problem (HTS circuits must be passified somehow)
  - More development effort required to optimize design

Recommendations

- If money was no option, the Turnstile OMT would provide the lowest noise receiver but…
  - We will need to design a new Dewar and receiver package
  - Assumes we can keep the signal in waveguide right up to the LNAs
  - Plus add a 4th Compressor (but this will allow opportunities to improve the cooling of L-Band receivers as well as increase compressor reliability)
- The Quadridge OMT is probably the best Model 22 option we have
  - Especially if the Turnstile all-waveguide OMT could not be cooled as low as the Quadridge without a Model 350
  - Will need to design a new Dewar & receiver package (largely complete)
- The HTS Planar OMT is an attractive option but if the decision had to be made today, it still has a number of concerns that need to be more fully addressed, such as…
  - Can the Insertion Loss, Input Return Loss and Cross-Pol/Isolation be improved and be made repeatable?
  - How do we tune the amplitude & phase match of the 90° Hybrid for good circular polarization Axial Ratio performance?
  - Will the HTS microstrip circuits be robust enough?

So it all depends on how much money the EVLA Program Manager has in his Contingency Fund and how low-noise a receiver the astronomers want in the 8-12 GHz band…

Backup Slides

T_{Rx} Summary

EVLA

Best, 2nd Best, 3rd Worst, Worst

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Estimated T_{Rx}(K) Model 350	10.9	12.4	13.8	19.4	TS in WG
	11.9	-	-	-	TS in Coax
Estimated T_{Rx}(K) Model 22	12.2	14.2	15.9 ?	23.3 ?	TS in WG
	13.5	-	-	-	TS in Coax
Estimated T_{Rx}(K), Model 22	15.7	17.2	-	-	OMT @ 50K

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