Replacing a Microwave Radio Test System on a Time Budget

Brian C. Thorson, AF6NA

Kerry Banke, N6IZW and Ed Munn, W6OYJ have been driving up from San Diego to the Los Angeles basin for the last 15 years to assist the San Bernardino Microwave Society (SBMS) with our annual "Microwave Tune-Up" event. The San Diego Microwave Group (SDMG) has been a close partner club with SBMS for many years and their members are very active in the microwave contests. It became apparent that 2015 was the year everything had to change because of equipment changes, vacations and schedule conflicts. We would need to come up with a new microwave test system.

Figure 1 – Kerry, N6IZW at the Microwave Test Bench

The objective was to replace the legacy (old) system for measurement of Effective Isotropic Radiated Power (EIRP) and Minimum Discernable Signal (MDS) used by the San Diego Microwave Group (SDMG) and the San Bernardino Microwave Society (SBMS) for their 10 GHz and 24 GHz radios since Year 2000. The difficult part was to do so in less than 2 months of lead time. Each year, usually in July, the Microwave Tune-Up event is held in a large regional park with enough open space to accommodate a 220-foot test range. The purpose is to help Amateur microwavers to get ready for the annual ARRL 10 GHz and Up Contest. The Tune-Up event reveals whether their radios are still working, and provides a relative ranking in MDS and an EIRP value proportional to output power and antenna gain.

Figure 2 – Microwave Rigs on the Test Line

Design Considerations

Engineering is always a game of tradeoffs, usually balancing maximum performance vs. practical reality. That is true in the project I am about to describe. While in years past, frequencies of 10, 24, 47, and 78 GHz have been measured, this paper will focus on 10 GHz. The legacy system was a combination of test instruments, a test fixture mounted atop a 15-foot tall mast, and an Excel spreadsheet that contained all the correction factors. A screen shot of the 10 GHz results in 2012 can be seen below.

August 4, 2012 SDMG-SBMS EIRP/MDS Event						Range Feet	220			89
10 GHz NB										Path Loss dB
Call	Dish size "	Output dBm	ERP PM dBm	Atten. Value dB	MDS Gen dBm	Calc Ant Gain	Calc ERP dBm	Meas ERP	Meas-Calc	
N6VI	12	33	-15	10	-73	27	60	53	-7	
W6IEE	12	30	-18	10	-68	27	57	50	-7	
N6RMJ1	30	39	-6	20	-89	35	74	72	-2	
N6RMJ2	23	32	-14	10	-82	33	65	54	-11	
W6QIW	30	39	-8	10	-71	35	74	60	-14	
N9RIN	30	40	-13	10	-70	35	75	55	-20	
AF6NA	33	35	-7	20	-84	36	71	71	0	
KH6WZ	30	38	-5	10	-68	35	73	63	-10	
W6SZ	29	23	-12	0	-67	35	58	46	N/A	
WB6DNX2	12DB	30	-19	0	-64	12	42	39	-3	
W6OYJ	30	28	-17	20	-80	35	63	61	-2	
KE6HPZ	24	39.3	-7	20	-80	33	73	71	-1	
WB6JDH	23	30	-15	10	-72	33	63	53	-10	
WB6NOA	23	27	-17	10	-67	33	60	51	-9	
KC6QHP	19	30	-13	10	-76	31	61	55	-6	
N9RIN-2	36	36	-10	10	-64	37	73	58	-15	
K6NKC	30	37	-14	20	-77	35	72	64	-8	
KB6CJZ	18	29	-12	0	-70	31	60	46	-14	

Figure 3 – 10 GHz EIRP / MDS Test Results in 2012

Measurement repeatability was an important consideration. I did not want our new system to produce results dramatically different from the previous few years. To maintain some portability of results from years past, I decided to keep the same test range distance and antenna mast height. This would, hopefully, yield the same microwave path loss as before. The microwave path loss and antenna gain calculations from the existing excel spreadsheet would also remain the same. Only the test fixture and cable losses would need to be substituted into the spreadsheet replacing the legacy system values. That way, calculated EIRP may come close to the prior years' values.

An important design task was to understand the system to be replaced. This included the range path attenuation, gains and losses in the test fixtures, the frequency conversion scheme and the spreadsheet math and correction factors. I found data going back to year 2000 using the legacy system. Kerry Banke, N6IZW was the designer and test engineer who implemented the legacy system and performed the tests. He would post the Tune-Up results to the SDMG web site. The data provided a range of readings and test results for many radios over the last 15 years. This enabled me to understand what would be needed from a test system in terms of dynamic range, that is how high a signal and how low a signal would need to be measured for EIRP and what levels of microwave power would need to be generated for the MDS tests. I created an Excel sheet for a summary of the measured EIRP and MDS levels since Y2000 and it is presented below.

	A	B	C	D	E	F	G	H
1	Values in dBm unless otherwise stated		ERP Value	ERP Value	ERP Dyn. Range	MDS Value	MDS Value	MDS Dyn. Range
2	Yr.	Club	low	hi	(dB)	low	hi	(dB)
3	2014	SBMS	36	76	40	58	90	32
4	2013	SBMS	35	76	41	52	90	38
5	2012	SBMS	39	72	33	64	89	25
6	2011	SBMS	36	76	40	15	94	79
7	2010	SBMS	37	77	40	41	93	52
8	2009	SBMS	33	74	41	70	90	20
9	2008	SBMS	43	76	33	57	94	37
10	2007	SBMS	35	80	45	32	95	63
11	2006	SBMS	48	79	31	51	92	41
12	2005	SBMS	41	78	37	40	94	54
13	2004	SBMS	56	76	20	78	100	22
14	2003	SBMS	28	77	49	60	90	30
15	2002	SBMS	39	65	26	65	92	27
16	2001	SBMS	33	66	33	50	82	32
17	2000	SBMS	22	73	51	19	111	92
18								
19		HIGH Range:		51	dB		92	dB
20		LOW Range:		20	dB		20	dB
21		AVG. Range:		37	dB		43	dB
22		Numeric Mean:		36	dB		56	dB
23		**Y2015 Range TARGET:**	**ERP:**	**53**	**dB**	**MDS:**	**63**	**dB**

Figure 4 – EIRP and MDS Results Summary Sheet

As can be seen from the summary of measured results, the largest range of EIRP levels occurred in year 2000, the first year of available data. That year, radio output levels spanned a range of 51 dB. For MDS, 2000 was also the year when the test system was challenged the most, requiring a 92 dB dynamic range. But since then, dynamic ranges have been smaller. Over the last 10 years, the highest EIRP value was 80 and the lowest, 33. For the same period, the lowest MDS value was 15 and the highest, 94. I chose dynamic range targets of 53 dB for EIRP and 63 dB for MDS. The new system should be able to accept a high value of +5 dBm during EIRP tests, and generate signals weaker than the MDS of microwave radios.

The Test Range

A concern raised at previous Tune-Up events was whether microwave rigs at the ends end of the test lineup were getting the same signal level as an operator who arrived early and set up his rig at the center of the test line, on the axis of the test fixture horn antenna. The answer to this question has to do with the maximum angle of the test range from the test fixture position to the ends of the lineup and the radiation pattern of the test antenna. Since the test fixture was going to change, a design opportunity presented itself to address the signal vs. angle concerns. It would be desirable to have a test antenna that illuminates the test line from one end to the other with minimal power density variation.

The test range traditionally used by SBMS is a section of a regional park in Orange County, CA. An aerial photo with distance lines drawn can be seen in Figure 5 below. The test line is the sidewalk at the edge of the parking lot. Microwave Ops take test positions that will “see” the test fixture at 220 feet down range.

While the test fixture has moved slightly from year to year, the results are, nevertheless, fairly repeatable. The approximate angle is 37 to 40 degrees.

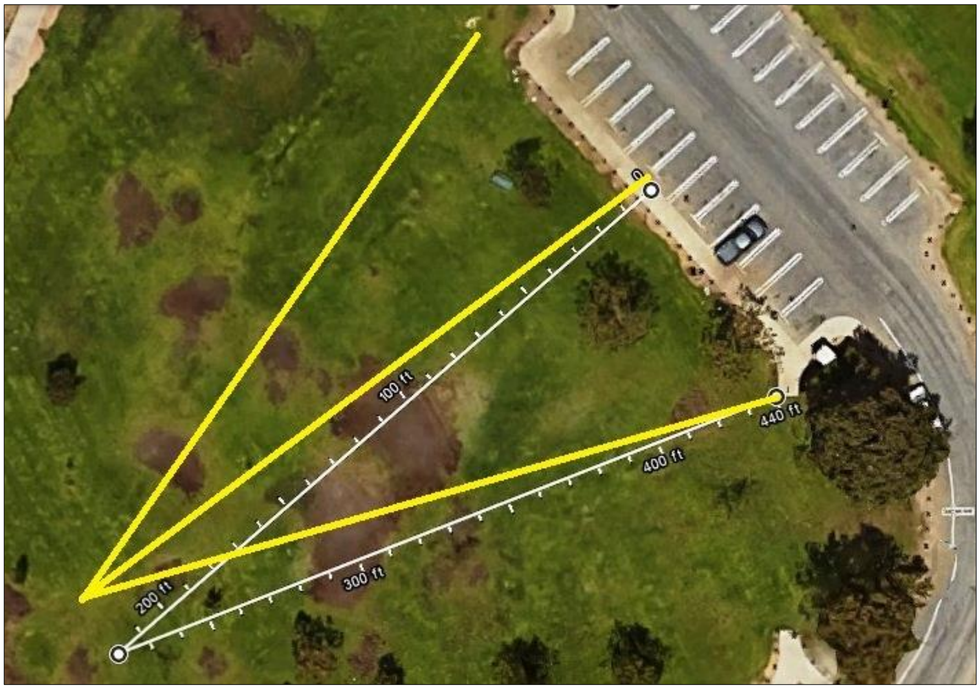

Figure 5 – Test Range Aerial Plot with Distance Lines

In general, a microwave horn of higher gain will have a narrower angle of radiation. On the other hand, a smaller antenna, one with less gain, will typically cover a wider angle of radiation. The reciprocal rule of antennas tells us that patterns for transmitting and receiving are the same. The smallest practical microwave antenna is an open waveguide. But what is the gain and illumination pattern of open waveguide? Online lookups on these questions yielded 3 reliable information sources, 2 commercial and one Amateur microwave source. Commercial waveguide probe suppliers publish a typical gain figure of 5 dB, isotropic (dBi), but what about the angle of radiation?

Paul Wade, W1GHZ, has done extensive testing and numeric modeling of microwave horn antennas. In his online antenna handbook, Appendix 6C, Electromagnetic Fields in Feed Antennas, Paul provides calculated microwave radiation patterns from open-ended WR-90 waveguide. See the circular graph below.

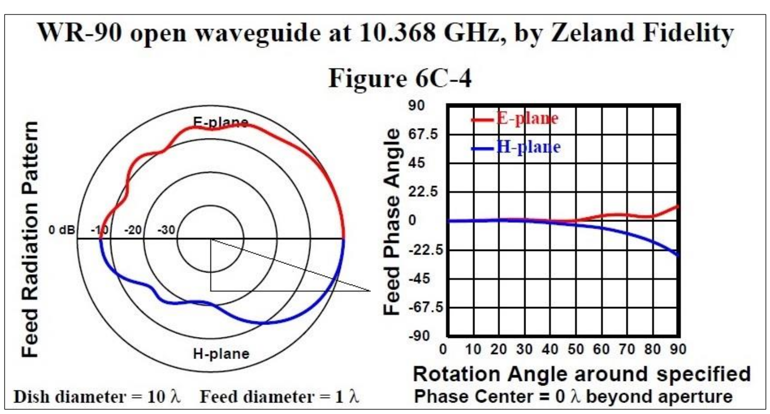

Figure 6 – Open WR-90 Waveguide Radiation Pattern – Source W1GHZ Online Antenna Book

In the above graph, the blue line is the one that applies to amateur 10 GHz, as most of the work is done in horizontal polarization. The superimposed triangle shows the approximately 20 deg. angle point occurs at an illumination value of about -1 dB. This should keep most of the operator's antennas illuminated at close to the same power density. So the design approach of using open waveguide seems to work well for this test application.

Test Instrumentation

At a recent SBMS meeting, I spoke with Bill Preston, KZ3G about a microwave analyzer on loan. Bill is the current Vice President of the Fullerton (CA) Radio Club (W6ULI). He said he could arrange to let SBMS use the analyzer for the Microwave Tune-Up range tests. The Agilent 9918A "Field Fox" Microwave Analyzer is a comprehensive and powerful test instrument with the capability of several test products integrated into one hand-held package. It has many automated test functions resident within the instrument software and a wide frequency range that extends up to 26.5 GHz.

I designed the microwave test system for year 2015 around the 9918A Analyzer, greatly simplifying the test fixture requirements. The Field Fox would generate accurate and stable MDS test signals at 10.368 GHz and 24.192 GHz and would also provide accurate power readings for EIRP. It is a perfect solution that cuts down design and implementation time greatly. The analyzer also has lots of memory to store test setups, so an operator never needs to remember long keystroke sequences to arrive at the correct test configuration. The Field Fox calls this the instrument "state." Once a test setup is finalized, it is saved as a "state," then the operator simply recalls that state for a new test, greatly improving measurement repeatability. A block diagram of the test solution for 2015 can be seen below.

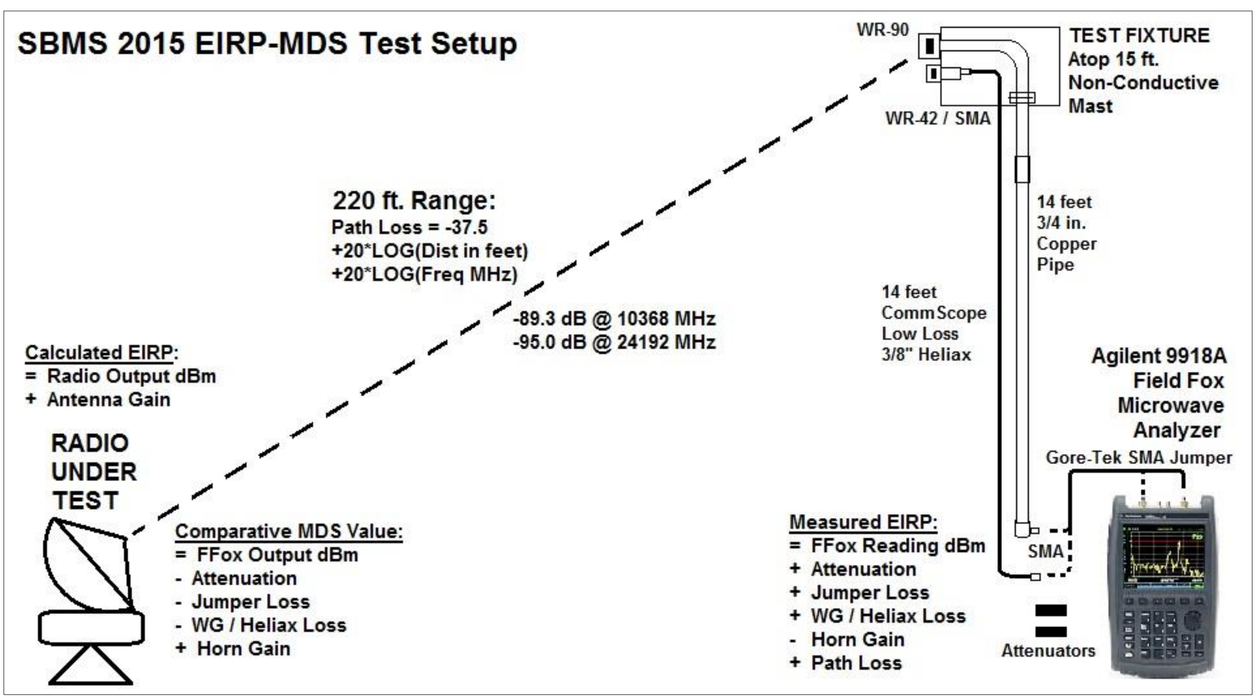

Figure 7 – SBMS Test System for 2015 Microwave Tune-Up

The Test Fixture

The legacy system used a test fixture that included 10.368 and 24.192 GHz signal sources. This year, we would not need to design and build that kind of fixture because the Agilent 9918A Field Fox would generate the necessary signals. The new fixture, as can be seen from the diagram above, was simply an antenna mast with ¾-inch copper pipe for low-cost waveguide and a transition to WR-90n rectangular guide with a 90-degree bend. I had built up a circular waveguide to SMA transition a couple of years ago and the Field Fox was wonderfully useful for evaluating the part. When tested in the “Return Loss” mode, the home-made transition exhibited a value of -18dB. This is comparable to many commercially available transitions. Using the “Insertion Loss” mode, the Field Fox revealed the entire waveguide run had a loss of only 0.7 dB. I repeated the measurement several times to be sure. Then I measured all the system components for loss and entered the values into the spreadsheet. Finally, we were ready to test.

As can be seen from the test a results below, the spreadsheet was modified from the one used before, but the results were not far off from previous years. One operator’s performance was equal to the calculated value, and 2 others came within 1 dB. Not a bad outcome for the first trial of a new test system.

SBMS EIRP-MDS Tune Up Sat. 25 JULY 2015

Range = 220 Ft. Path Loss= 89.3 dB

10 GHz: Meas. Sys Loss = -3.1 dB

Callsign	Reflector Size (inches)	Radio Output (dBm)	EIRP Reading (dBm)	Syst. Loss (dB)	Calc. Ant. Gain (dBi)	Calc. EIRP (dBm)	Meas. EIRP (dBm)	Meas.-Calc. (dB)	Conditions	MDS Gen. (dBm)	MDS Attn. (dB)	Comp. MDS value
N5BF	29.5	38.5	-49.5	30.9	35	74	71	-3		-32	65	-94
KK6MXP	17.8	26.0	-71.5	30.9	31	57	49	-8		-34	65	-96
AF6NA	32.8	39.1	-44.6	30.9	36	75	76	1		-42	65	-104
W6SZ	29.5	23.0	-74.0	30.9	35	58	46	-12		-42	65	-104
WB6DNX	3.7	23.0	-70.5	30.9	17	40	50	10	HORN	-4	65	-66
WB6DNX2	3.7				17				HORN	-8	65	-70
WB6DNX3	1.6	23.0	-81.8	30.9	10	33	38	5	OMNI			
N6RMJ	29.5	38.5	-46.0	30.9	35	74	74	1		-40	65	-102
N6RMJ2	29.5				35				RETEST	-42	65	-104
N6RMJ3	29.5				35				RETEST	-44	65	-106
N6RMJ4	29.5				35				RETEST	-34	72	-103
N6RMJ5	29.5	38.5	-46.0	30.9	35	74	74	1	NEW POS.			
WA6CDR	72.0	38.0	-50.0	30.9	43	81	70	-11		-41	72	-110
WA6CDR2	72.0	38.0	-39.5	30.9	43	81	81	0	RETEST	-41	72	-110
WA6CDR3	72.0	38.0	-39.0	30.9	43	81	81	0	RETEST			
WB6NOA	24	30.5			33	64			RIG DOWN			

Figure 8 – SBMS 2015 Microwave Tune-Up Results for 10 GHz