Breitbandiger Leistungsadapter -50 dB [#84]

DL6DCA 11.08.2026

Bild 1: realisierter -51 dB Leistungsadapter

Auf dem Labortisch liegen häufig Funkgeräte die eine Ausgangsleistung von 5 W bis zu 100 W (+50 dBm) haben. Da die meisten einfachen Messgeräte aber nur 10 mW (+10 dBm) am Eingang vertragen, muss sorgfältig darauf geachtet werden, dass durch Einfügen von entsprechenden Dämpfungsgliedern das TX-Signal beim Messvorgang entsprechend gedämpft wird. Dazu nimmt man üblicherweise entsprechende Dämpfungsglieder. Sie haben den Vorteil breitbandig zu sein, sodass auch die Bewertung von Oberwellen z.B. mit einem TinySA möglich ist.

Wenn man aber mehrere Messgeräte zusammen betreibt, wird es schon etwas schwieriger. Angeregt durch einen Youtube Beitrag von Ralph Gable **[1]** in dem er eine breitbandige -50 dB Leistungsauskopplung beschreibt, kam ich auf die Idee diesen Vorschlag umzusetzen. Der Schaltung liegt ein QST-Artikel aus dem Jahre 2001 zugrunde **[2]**, der als Anhang beigefügt ist. Weitere Youtuber haben das Thema ebenfalls aufgegriffen **[3]**, **[4]**, **[5]**.

Bild 2: Lösung aus [5]

Vom Grundsatz her handelt es sich um einen 50 Ω Leiter als Durchgang, an dem ein Spannungsteiler angeschlossen ist.

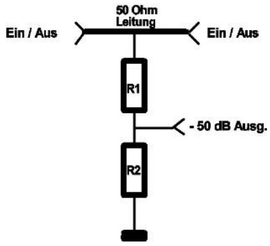


Bild 3: Schaltung

Da die Messgeräte üblicherweise eine Eingangsimpedanz von 50 Ω haben, ist R2 als 50 Ω Widerstand ausgelegt.

Weshalb wurde ein – 50 dB Ausgang gewählt? Natürlich ist jede andere Konstellation denkbar, aber bei einer Durchgangsleistung von 100 W = + 50 dBm macht es Sinn, diesen Pegel auf + 1 mW = 0 dBm abzusenken. Dadurch hat man eine gewisse Sicherheit zum Schutz des Messgerätes mit seinem max + 10 dBm Eingang.

Die Bemessung von R1 ist recht einfach. An der 50 Ω Leitung liegt bei 100 W eine Spannung von P = U x I , mittels URI umgestellt auf P = U^2 / R , weiter umgestellt auf

$\sqrt[2]{P\ x\ R} = U \quad \sqrt[2]{100\ x\ 50} = 70{,}711\ V$.

Am Ausgang sollen 1 mW anliegen, also $\sqrt[2]{0{,}001\ x\ 50} = 0{,}225\ V$.

Bei der Berechnung des Widerstandes R1 ist zu beachten, dass bei angeschlossenem Messgerät dessen 50 Ω Innenwiderstand parallel zu R2 zu liegen kommt und somit nicht 50 Ω sondern 25 Ω in die Rechnung einfließen müssen.

R 2 = (70,711 / 0,225) x 25 = 7856,777 Ω .

Stellt sich jetzt auch noch die Frage, welcher Belastung insbesondere R1 ausgesetzt ist.

Gem. P = U^2 / R ergibt sich (70,711 x 70,711) / 7857 = 0,636 W, also ein beachtliche Leistung. Leistungswiderstände auf Widerstandsdrahtbasis sind schon wegen der Eigeninduktivität für eine solche Schaltung nicht brauchbar. Ich habe mich für die von Ralph [1] vorgeschlagenen 1 Watt SMD 2512 Widerstände entschieden. Es handelt sich um drei 2,61 kΩ 1% Widerstände, von denen drei in Reihe geschalten einen Gesamtwiderstand von 7830 Ω ergeben, was dicht am errechneten Wert von 7856 Ω liegt. Jeder Widerstand wird somit nur mit 0,636 / 3 = 0,212 W belastet. R2 habe ich mit zwei parallel geschalteten 100 Ω SMD 1206 in ½ Watt Ausführung realisiert.

Alle o.a. YT-Quellen haben den HF-Durchgang zwischen den Anschlussbuchsen durch eine Metallplatte realisiert, wie man beispielhaft auf Bild 2 erkennen kann. Diese Platte hat eine definierte Größe, um in dem gewählten Aluminiumgehäuse einen 50 Ω Übergang zu schaffen. Meine Frage war, warum nutzen die nicht einfach eine Platine mit 50 Ω Stripline, die HF-technisch doch besser sein müsste?

Mittels AppCAD **[6]** habe ich die Leiterbahn berechnet und mittels SprintLayout von Abacom eine Platine auf 1,6 mm FR4 Basis entworfen. Diese habe ich sehr preisgünstig in Fernost von PCBway anfertigen lassen. Nach der Bestückung und ersten Vermessungen musste diese jedoch noch einmal korrigiert werden, da die von mir unter dem Spannungsteiler angeordnete

Massefläche eine zu hohe Kapazität ergab und sich nicht sinnvoll abgleichen ließ. Also umgezeichnet und diesmal in DL bei AISLER bestellt. Ging recht schnell, aber ich hatte vergessen ohne Lötstopplack zu bestellen. Somit blieb mir nichts anderes über, als alle Lötstellen mittels Messer und Glasfaserradierer freizulegen. Insofern schon wieder etwas dazugelernt.

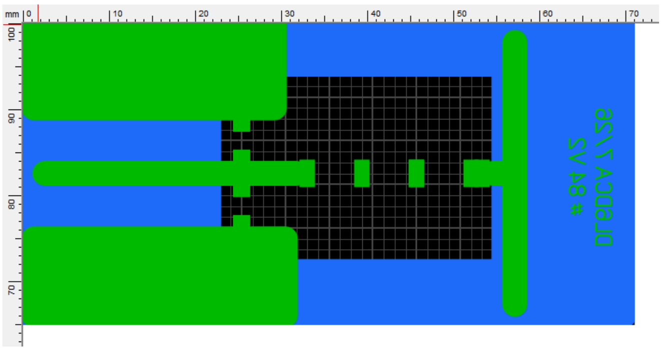


Bild 4: Platinenlayout

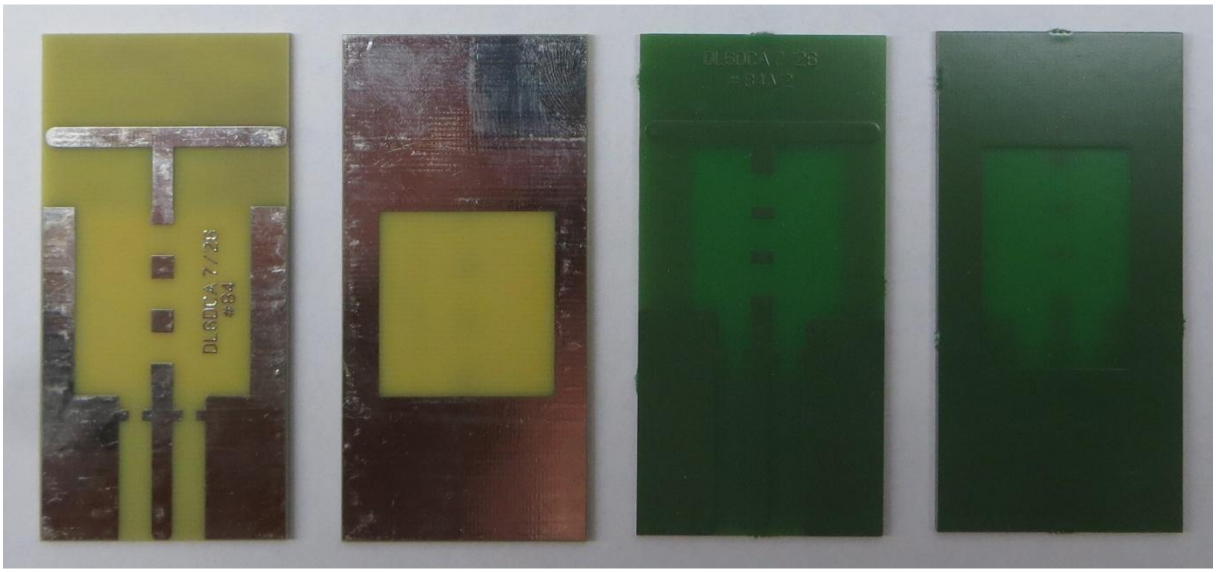


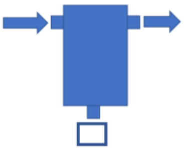
Bild 5: links die erste Version, in grün die Endversion (leider voller Lötstopplack)

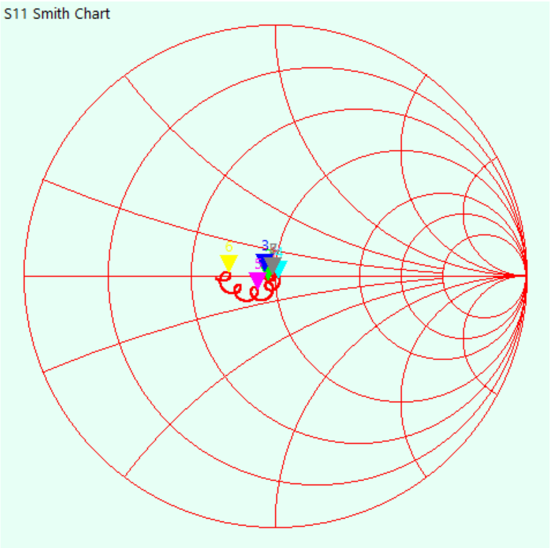
Die Platine wurde in ein Schubert Weißblechgehäuse 70 x 30 x 30 mm eingelötet. Als Buchsen habe ich N-Norm gewählt und diese nicht verschraubt, sondern verlötet. Auf Bild 6 erkennt man einen roten Draht. Dieser Draht ist mit der Durchgangsleitung verbunden und wirkt auf die Widerstände wie ein Kondensator; der Frequenzgang lässt sich durch Verbiegen des Drahtes korrigieren.

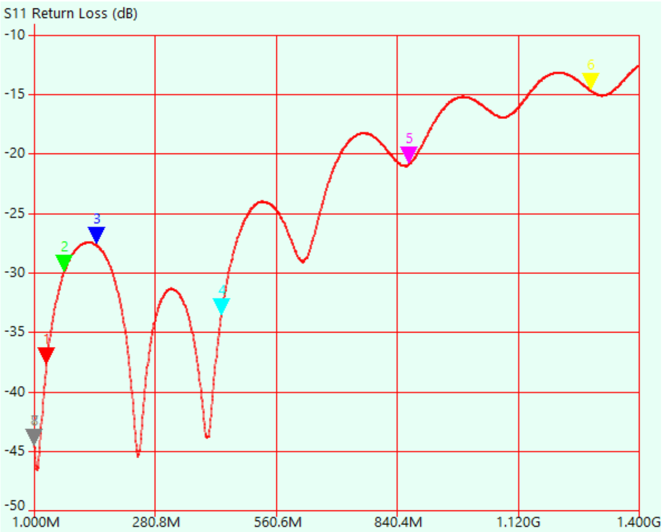
Bilder 6 + 7: Bestückte Platine im Gehäuse Vorder- und Rückseite

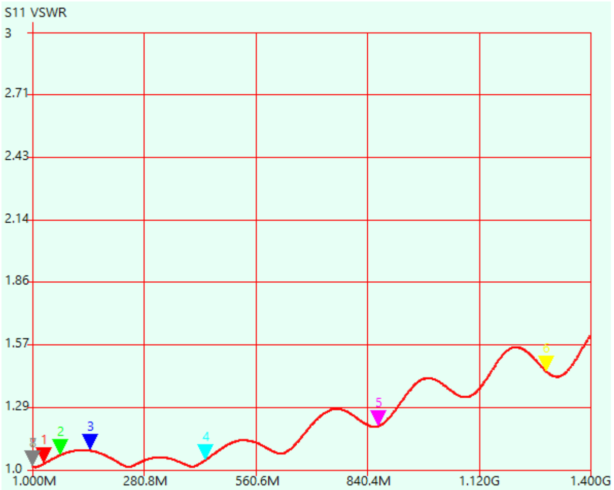
Nun zur Vermessung der Konstruktion:

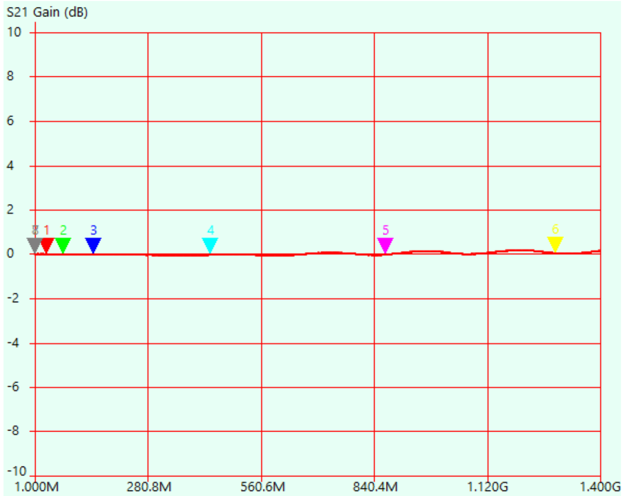
Als erstes wurde das Verhalten der Durchgangsleitung (Thru) getestet, der Messausgang (Out) mit 50 Ω Abschlusswiderstand abgeschlossen.











Marker 1

Frequency:	30.2619 MHz	Parallel L:	-10.957 µH
Impedance:	49.4-j1.17 Ω	Parallel C:	2.5245 pF
Series R:	49.404 Ω	VSWR:	1.027
Series X:	4.4866 nF	Return loss:	-37.569 dB
Series L:	-6.165 nH	Quality factor:	0.024
Series C:	4.4866 nF	S11 Phase:	-116.29°
Parallel R:	49.431 Ω	S21 Gain:	-0.036 dB

Marker 2

Frequency:	70.6713 MHz	Parallel L:	-2.4894 µH
Impedance:	47.6-j2.05 Ω	Parallel C:	2.0373 pF
Series R:	47.555 Ω	VSWR:	1.068
Series X:	1.0987 nF	Return loss:	-29.710 dB
Series L:	-4.616 nH	Quality factor:	0.043
Series C:	1.0987 nF	S11 Phase:	-138.82°
Parallel R:	47.643 Ω	S21 Gain:	-0.038 dB

Marker 3

Frequency:	144.523 MHz	Parallel L:	2.0449 µH
Impedance:	46.2+j1.15 Ω	Parallel C:	-593.06 fF
Series R:	46.218 Ω	VSWR:	1.086
Series X:	1.2676 nH	Return loss:	-27.726 dB
Series L:	1.2676 nH	Quality factor:	0.025
Series C:	-956.72 pF	S11 Phase:	162.39°
Parallel R:	46.246 Ω	S21 Gain:	-0.054 dB

Marker 4

Frequency:	434.355 MHz	Parallel L:	-533.49 nH
Impedance:	51.6-j1.83 Ω	Parallel C:	251.67 fF
Series R:	51.593 Ω	VSWR:	1.049
Series X:	200.17 pF	Return loss:	-32.438 dB
Series L:	-670.75 pH	Quality factor:	0.035
Series C:	200.17 pF	S11 Phase:	-47.93°
Parallel R:	51.658 Ω	S21 Gain:	-0.068 dB

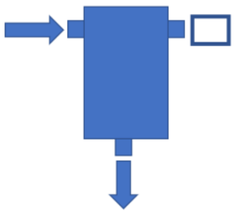
Marker 5

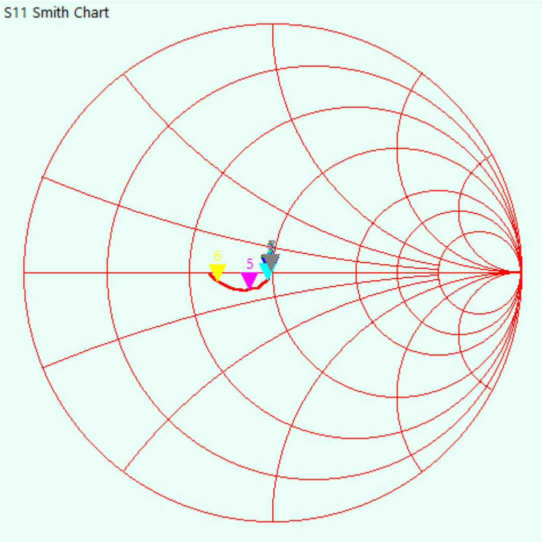
Frequency:	867.711 MHz	Parallel L:	-57.979 nH
Impedance:	42.6-j5.85 Ω	Parallel C:	580.26 fF
Series R:	42.592 Ω	VSWR:	1.226
Series X:	31.37 pF	Return loss:	-19.851 dB
Series L:	-1.0725 nH	Quality factor:	0.137
Series C:	31.37 pF	S11 Phase:	-138.10°
Parallel R:	43.394 Ω	S21 Gain:	-0.059 dB

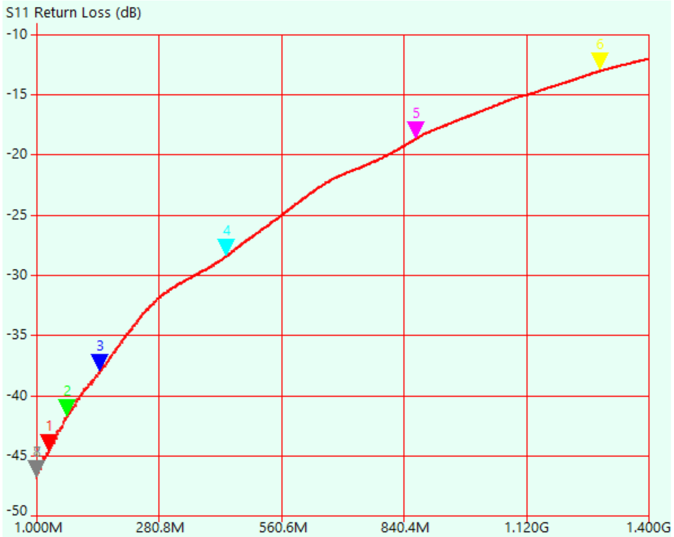
Marker 6

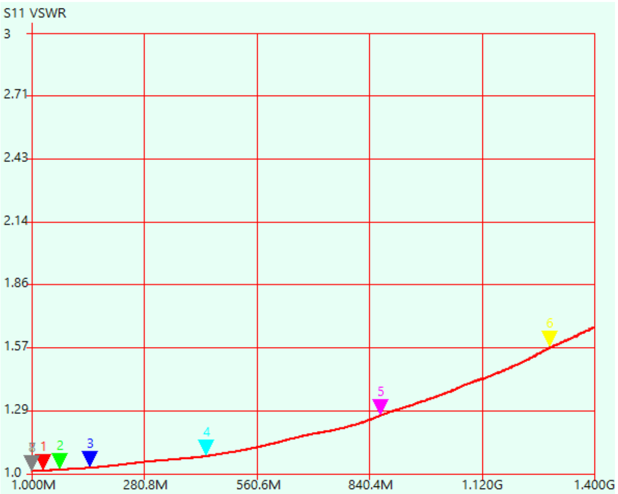
Frequency:	1.28992 GHz	Parallel L:	390.06 nH
Impedance:	33.2+j349m Ω	Parallel C:	-39.029 fF
Series R:	33.207 Ω	VSWR:	1.506
Series X:	43.042 pH	Return loss:	-13.899 dB
Series L:	43.042 pH	Quality factor:	0.011
Series C:	-353.69 pF	S11 Phase:	178.57°
Parallel R:	33.211 Ω	S21 Gain:	0.012 dB

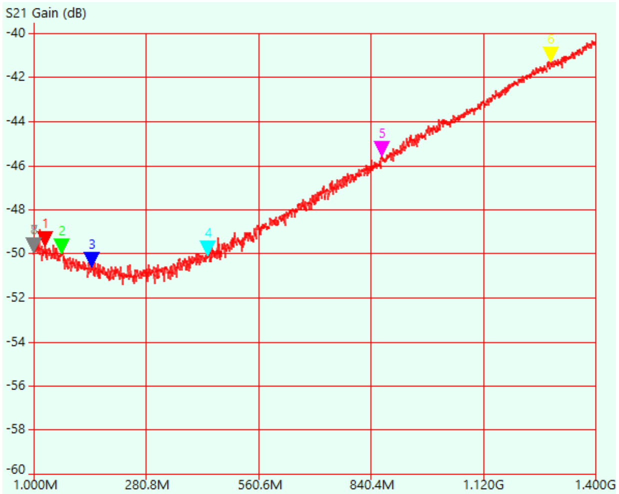
Als zweites wurde von einem Thru Eingang zu Messbuchse Out gemessen; der zweite Thru Zugang wurde mit 50 Ω abgeschlossen.











Marker 1

Frequency:	30.2619 MHz	Parallel L:	-45.555 µH
Impedance:	49.5-j283m Ω	Parallel C:	607.16 fF
Series R:	49.5 Ω	VSWR:	1.012
Series X:	18.592 nF	Return loss:	-44.772 dB
Series L:	-1.4878 nH	Quality factor:	0.006
Series C:	18.592 nF	S11 Phase:	-150.33°
Parallel R:	49.502 Ω	S21 Gain:	-49.774 dB

Marker 2

Frequency:	70.6713 MHz	Parallel L:	-9.5863 µH
Impedance:	49.4-j574m Ω	Parallel C:	529.06 fF
Series R:	49.438 Ω	VSWR:	1.016
Series X:	3.9217 nF	Return loss:	-41.852 dB
Series L:	-1.2933 nH	Quality factor:	0.012
Series C:	3.9217 nF	S11 Phase:	-134.05°
Parallel R:	49.445 Ω	S21 Gain:	-50.109 dB

Marker 3

Frequency:	144.523 MHz	Parallel L:	-2.7222 µH
Impedance:	49.3-j982m Ω	Parallel C:	445.5 fF
Series R:	49.259 Ω	VSWR:	1.025
Series X:	1.1215 nF	Return loss:	-38.136 dB
Series L:	-1.0814 nH	Quality factor:	0.02
Series C:	1.1215 nF	S11 Phase:	-126.48°
Parallel R:	49.278 Ω	S21 Gain:	-50.694 dB

Marker 4

Frequency:	434.355 MHz	Parallel L:	-265.07 nH
Impedance:	48.2-j3.23 Ω	Parallel C:	506.52 fF
Series R:	48.207 Ω	VSWR:	1.078
Series X:	113.55 pF	Return loss:	-28.503 dB
Series L:	-1.1824 nH	Quality factor:	0.067
Series C:	113.55 pF	S11 Phase:	-117.18°
Parallel R:	48.423 Ω	S21 Gain:	-50.168 dB

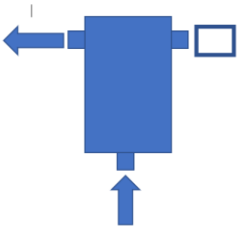
Marker 5

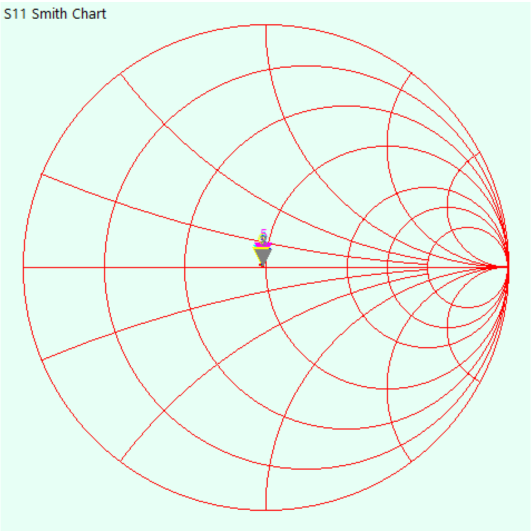
Frequency:	867.711 MHz	Parallel L:	-53.841 nH
Impedance:	41.2-j5.92 Ω	Parallel C:	624.85 fF
Series R:	41.249 Ω	VSWR:	1.261
Series X:	31.007 pF	Return loss:	-18.747 dB
Series L:	-1.085 nH	Quality factor:	0.143
Series C:	31.007 pF	S11 Phase:	-142.23°
Parallel R:	42.097 Ω	S21 Gain:	-45.694 dB

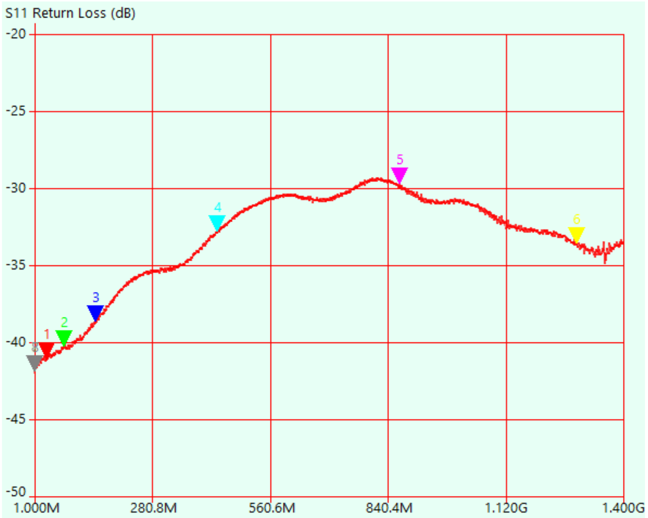
Marker 6

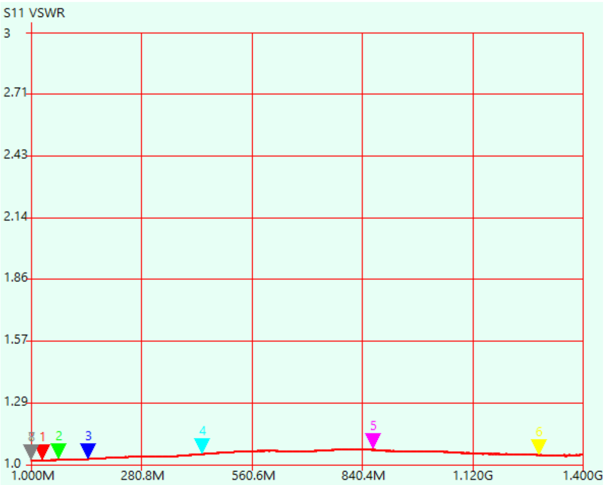
Frequency:	1.28992 GHz	Parallel L:	-51.219 nH
Impedance:	32-j2.48 Ω	Parallel C:	297.23 fF
Series R:	31.969 Ω	VSWR:	1.570
Series X:	49.815 pF	Return loss:	-13.076 dB
Series L:	-305.6 pH	Quality factor:	0.077
Series C:	49.815 pF	S11 Phase:	-170.45°
Parallel R:	32.161 Ω	S21 Gain:	-41.408 dB

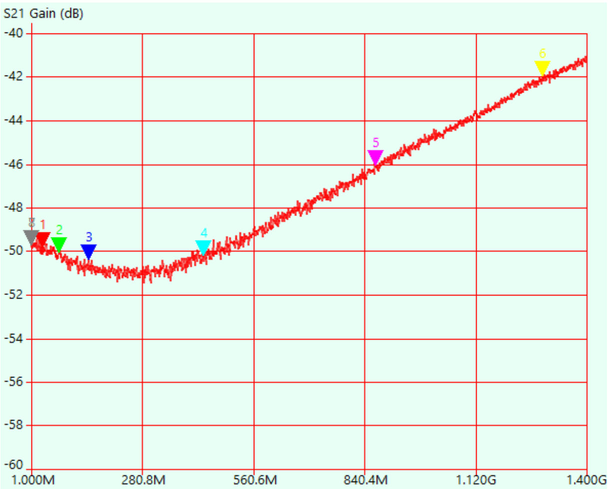
Abschließend noch die S22 Messung, also in den Messausgang rein zum Thru Eingang:











Marker 1

Frequency:	30.2619 MHz	Parallel L:	835.73 µH
Impedance:	49.1+j15.2m Ω	Parallel C:	-33.096 fF
Series R:	49.129 Ω	VSWR:	1.018
Series X:	79.885 pH	Return loss:	-41.127 dB
Series L:	79.885 pH	Quality factor:	0
Series C:	-346.24 nF	S11 Phase:	178.99°
Parallel R:	49.129 Ω	S21 Gain:	-49.900 dB

Marker 2

Frequency:	70.6713 MHz	Parallel L:	69.087 µH
Impedance:	49.1+j78.5m Ω	Parallel C:	-73.41 fF
Series R:	49.059 Ω	VSWR:	1.019
Series X:	176.68 pH	Return loss:	-40.416 dB
Series L:	176.68 pH	Quality factor:	0.002
Series C:	-28.705 nF	S11 Phase:	175.19°
Parallel R:	49.059 Ω	S21 Gain:	-50.155 dB

Marker 3

Frequency:	144.523 MHz	Parallel L:	5.8108 µH
Impedance:	48.9+j454m Ω	Parallel C:	-208.7 fF
Series R:	48.95 Ω	VSWR:	1.023
Series X:	500.11 pH	Return loss:	-38.739 dB
Series L:	500.11 pH	Quality factor:	0.009
Series C:	-2.4249 nF	S11 Phase:	156.35°
Parallel R:	48.954 Ω	S21 Gain:	-50.469 dB

Marker 4

Frequency:	434.355 MHz	Parallel L:	441.91 nH
Impedance:	49+j1.99 Ω	Parallel C:	-303.82 fF
Series R:	49.003 Ω	VSWR:	1.046
Series X:	730.77 pH	Return loss:	-32.950 dB
Series L:	730.77 pH	Quality factor:	0.041
Series C:	-183.73 pF	S11 Phase:	115.40°
Parallel R:	49.084 Ω	S21 Gain:	-50.268 dB

Marker 5

Frequency:	867.711 MHz	Parallel L:	145.09 nH
Impedance:	49.1+j3.06 Ω	Parallel C:	-231.87 fF
Series R:	49.07 Ω	VSWR:	1.067
Series X:	560.48 pH	Return loss:	-29.836 dB
Series L:	560.48 pH	Quality factor:	0.062
Series C:	-60.025 pF	S11 Phase:	105.16°
Parallel R:	49.26 Ω	S21 Gain:	-46.118 dB

Marker 6

Frequency:	1.28992 GHz	Parallel L:	225.48 nH
Impedance:	48.4+j1.28 Ω	Parallel C:	-67.515 fF
Series R:	48.422 Ω	VSWR:	1.042
Series X:	158.42 pH	Return loss:	-33.696 dB
Series L:	158.42 pH	Quality factor:	0.027
Series C:	-96.098 pF	S11 Phase:	140.11°
Parallel R:	48.457 Ω	S21 Gain:	-42.035 dB

Abschließend habe ich den Leistungsadapter mit meiner großen Dummyload abgeschlossen und auch den Messausgang mit einem 50 Ω Abschluss versehen. Weil gerade der Transceiver im 6 m Band eingestellt war, wurde 100 W auf 50 MHz in die Messvorrichtung gegeben und die Wärmeentwicklung mittels Wärmebildkamera beobachtet. Zum Messzeitpunkt war es im Shack mit 27° C schon recht warm. Die Temperatur im Bereich des Spannungsteilers stieg innerhalb von 40 sec. auf 67,5 ° C und stabilisierte sich dort.

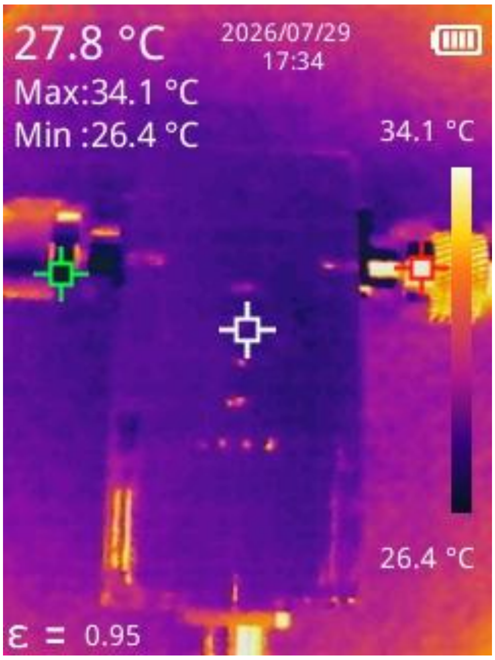


Bild 8: Messbeginn

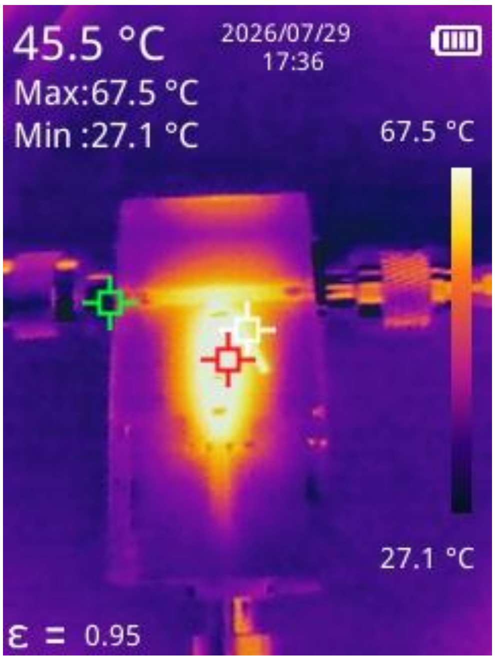


Bild 9: nach ca. 1 min mit 100 W auf 50 MHz

Auswertung / Beurteilung:

Wenn man sich die Dämpfung einmal anschaut

30 MHz	=	-49,774 dB
70 MHz	=	-50,109 dB
145 MHz	=	-50,694 dB
435 MHz	=	-50,168 dB
868 MHz	=	-45,694 dB
1290 MHz	=	-41,408 dB

stellt man fest, dass im Bereich zwischen 1 und 500 MHz die Abweichung unter 1 dB liegt. Über 500 MHz wird es dann doch recht ungenau, was darauf zurückzuführen ist, dass der Spannungsteiler bei den höheren Frequenzen aufgrund seiner induktiven und kapazitiven Blindkomponenten das Ergebnis verfälscht. Das Ergebnis liegt im Bereich, wie in der Ursprungsveröffentlichung **[2]** angegeben wurde und wie es auch vom HF-technischen Aufbau zu erwarten ist. Für genaue Messungen bleibt es bei der Nutzung von Durchgangsdämpfern; zur allgemeinen Übersicht und Einschätzung reicht der Leistungsadapter aber aus.

Ich werde diesen Leistungsadapter vor meiner Dummyload installieren, wo ich auch schon einen R&S URY Leistungsmesskopf habe. Dann besteht die Möglichkeit entweder den Frequenzzähler oder alternativ den Spektrumanalyser mit diesem Messaufbau zusätzlich zur bisherigen alleinigen Leistungsmessung gleichzeitig zu nutzen.

Warnung: Dieser Leistungsadapter funktioniert nur im Zusammenhang mit einem 50 Ω System. Das kann also eine Dummyload oder auch eine angepasste Antenne sein. Ohne impedanzrichtigen Abschluss des Thru Durchgangs, können am Messport höhere Pegel anstehen, die ggfs. das angeschlossene Messgerät gefährden. Für auftretende Schäden haftet jeder Anwender selber.

Es besteht selbstverständlich die Möglichkeit den Auskoppelgrad, hier -50 dB, auch zu verändern. Dabei sollte aber Augenmerk auf die entstehende Wärmeleistung des Spannungsteilers gelegt werden.

Über Rückfragen, Anmerkungen, Verbesserungsvorschläge würde ich mich freuen. Kontakt bitte per Mail dl6dca@darc.de oder Ortsfrequenz 144,575MHz.

73 de Wilhelm DL6DCA

[1] https://www.youtube.com/watch?v=Xd4BK6n4YUU&t=1037s

[2] https://on4khg.be/wordpress/wp-content/uploads/2015/02/Simple-RF-Power-measurement-W7ZOI-W7PUA.pdf

[3] https://www.youtube.com/watch?v=c768fWS7ONI

[4] https://www.youtube.com/watch?v=7T3oHO8jYHI

[5] https://www.youtube.com/watch?v=fKPG1FWcB5c

[6] https://www.darc.de/fileadmin/filemounts/distrikte/o/ortsverbaende/38/Downloads/Bericht_Berechnung_von_Leiterbahnen_auf_Platinen.pdf

By Wes Hayward, W7ZOI, and Bob Larkin, W7PUA

Simple RF-Power Measurement

PHOTOS BY JOE BOTTIGLIERI, AA1GW

Making power measurements from *nanowatts* to 100 watts is easy with these simple homebrewed instruments!

Measuring RF power is central to almost everything that we do as radio amateurs and experimenters. Those applications range from simply measuring the power output of our transmitters to our workbench experimentations that call for measuring the LO power applied to the mixers within our receivers. Even our receiver S meters are power indicators.

The power-measuring system described here is based on a recently introduced IC from Analog Devices: the AD8307. The core of this system is a battery operated instrument that allows us to directly measure signals of over 20 mW (+13 dBm) to less than 0.1 nW (–70 dBm). A tap circuit supplements the power meter, extending the upper limit by 40 dB, allowing measurement of up to 100 W (+50 dBm).

The Power Meter

The cornerstone of the power-meter circuit shown in Figure 1 is an Analog Devices AD8307AN logarithmic amplifier IC, U1. Although you might consider the

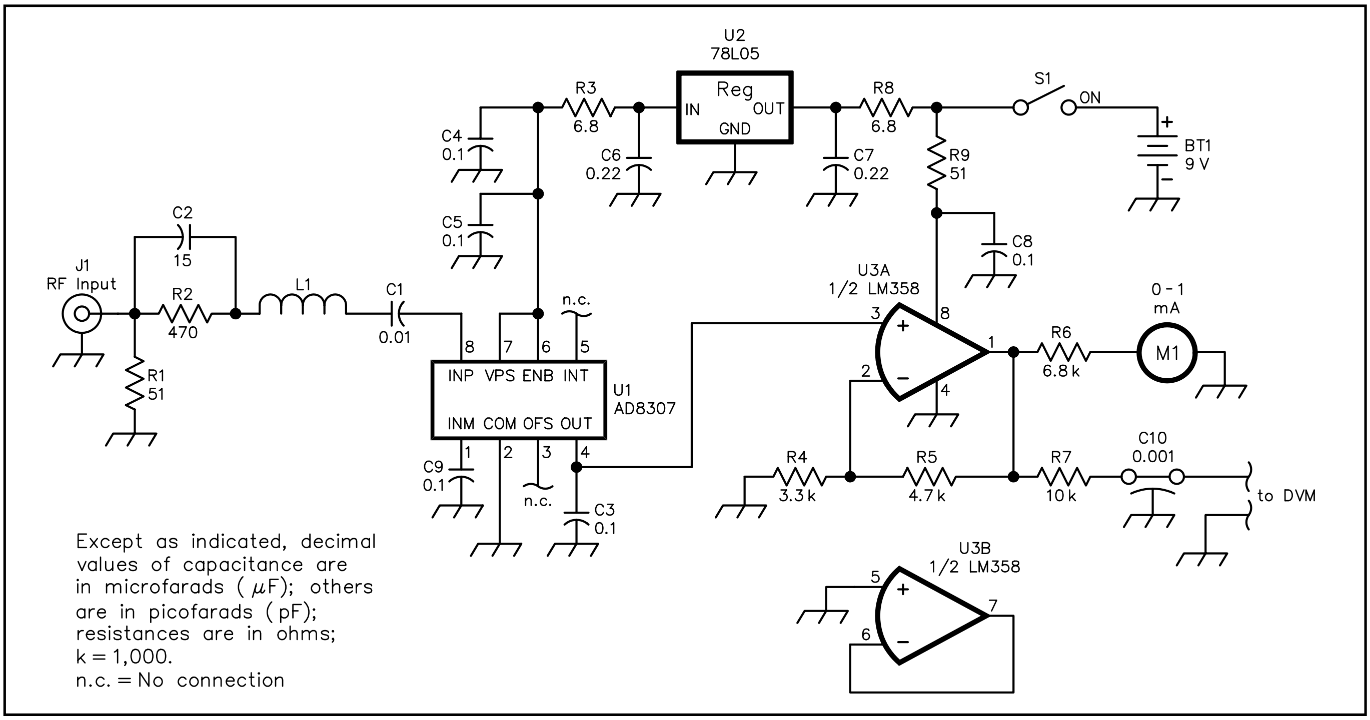


Figure 1—Schematic of the 1- to 500-MHz wattmeter. Unless otherwise specified, resistors are 1/4-W 5%-tolerance carbon-composition or metal-film units. Equivalent parts can be substituted; n.c. indicates no connection. Most parts are available from Kanga US; see Note 2.

J1—N or BNC connector
L1—1 turn of a C1 lead, 3/16-inch ID; see text.
M1—0-15 V dc (RadioShack 22-410); see text.
S1—SPST toggle
U1—AD8307; see Note 1.
U2—78L05
U3—LM358
Misc: See Note 2; copper-clad board, enclosure (Hammond 1590BB, RadioShack 270-238), hardware.

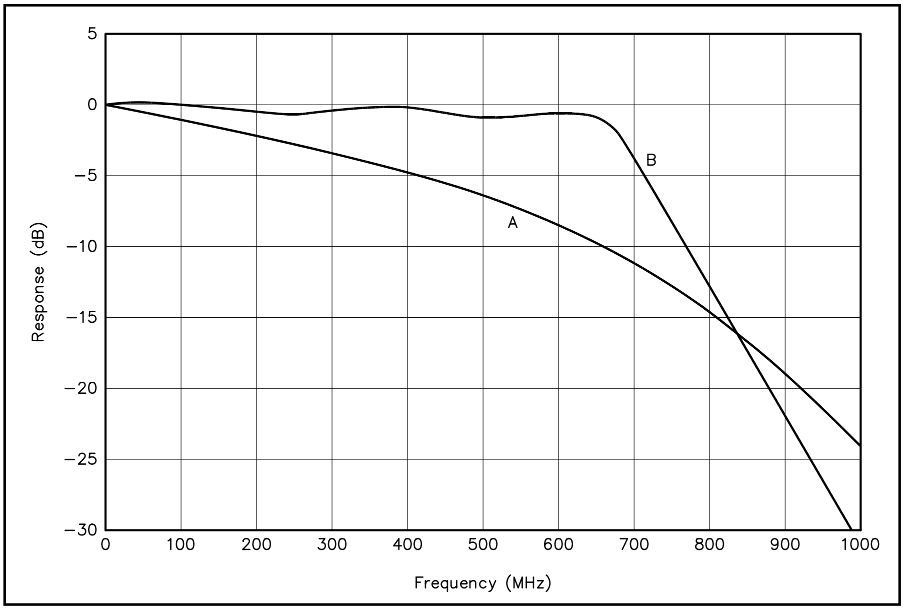


Figure 2—Response curves for the power meter before (A) and after (B) addition of R2, C2 and L1.

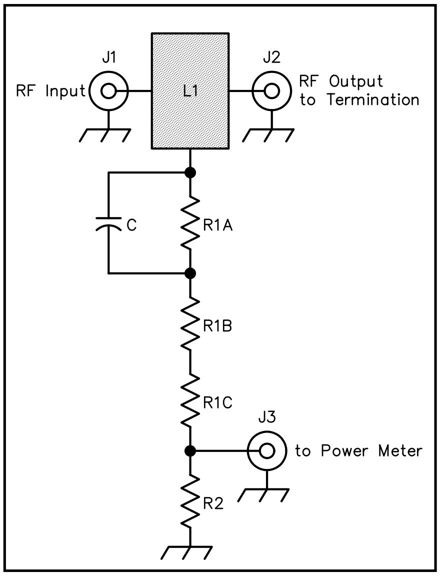


Figure 3—A tap that attenuates a high-power signal for use with the power meter. See the text and Figure 4 for discussion of the capacitor, C.

J1, J2—N connectors; see text.
J3—BNC connector
L1—1×1 1/2-inch piece of sheet brass; see text.
R1A-R1C—Three series-connected, 820-Ω, 1/2-W carbon film
R2—51-Ω, 1/4-W carbon film

IC as slightly expensive at about $10 in single quantities, its cost is justified by the wide dynamic range and outstanding accuracy offered. You can order the part directly from the Analog Devices Web site, which also offers a device data sheet.[1,2]

U1's power supply can range from 2.7 to 5.5 V. A 5-V regulator, U2, provides stable power for U1. U3, an op amp serving as a meter driver completes the circuit. U1's dc output (pin 4) changes by 25 mV for each decibel change in input signal. The dc output is filtered by a 0.1 μF capacitor and applied to the noninverting input of U3, which is set for a voltage gain of 2.4. The resulting signal with a 60 mV/dB slope is then applied to a 1-mA meter movement through a 6.8-kΩ multiplier resistor. When the circuit is driven at the 10-mW level, U3's output is about 6 V. U3's gain-setting resistors are chosen to protect the meter against possible damage from excessive drive.

U1 has a low-frequency input resistance of 1.1 kΩ. This combines with the resistances of R1 and R2 to generate a 50-Ω input for the overall circuit. R2 in parallel with C2 form a high-pass network that flattens the response through 200 MHz. L1, a small loop of wire made from a lead of C1, modifies the low-pass filtering related to the IC input capacitance, extending the response to over 500 MHz.

M1 is a RadioShack dc voltmeter. Although sold as a *voltmeter*, it actually is a 0-1 mA meter movement supplied with an external 15-kΩ multiplier resistor. The 0 to 15 V scale is used with a calibration curve that is taped to the back of the instrument to provide output readings in dBm. The dBm units can be converted to milliwatts by using a simple formula, although dBm readout is generally more useful and convenient.[3]

An auxiliary output from C10, a feedthrough capacitor, is provided for use with an external digital voltmeter or an oscilloscope for swept measurements.[4] We use the DVM when resolution is important. The analog movement can be read to about 1 dB, which is useful when adjusting or tuning a circuit. Enterprising builders might program a PIC processor to drive a digital display with a direct reading in dBm.

The first power meter we built did not include R2, C2 and L1. That instrument was accurate in the HF spectrum and useful beyond. Adding the compensation components produced an almost flat response extending beyond 500 MHz with an error of only 0.5 dB. The compensation network reduces the sensitivity by about 3 dB at HF, but boosts it at UHF. If your only interest is in the HF and low-VHF spectrum through 50 MHz, you can simplify the input circuit by omitting R2, C2 and L1. The responses before and after compensation are shown in Figure 2.

The power meter is constructed "dead-bug" fashion without need of a PC board. It is breadboarded on a strip of copper clad PC-board material held in place by the BNC input connector. R1 is soldered between the center pin and ground with short leads. U1 is placed about 3/4 inch from the input in dead-bug fashion (leads up) with pins 1 and 8 oriented toward J1. The IC is held to the ground foil by grounded pin 2 and bypass capacitors C3, C4 and C5. R2 and C2 are connected to the J1 center pin with short leads. L1 is formed by bending the lead of C1 in a full loop. Use a 3/16-inch-diameter drill bit as a winding form. None of the remaining circuitry is critical. It is important to mount the power meter components in a shielded box. We used a Hammond 1590BB enclosure for one meter and a RadioShack box for the other, with good shielding afforded by both. *Don't use a plastic enclosure for an instrument of this sensitivity*.

Higher Power

Transmitter powers are rarely as low as the maximum that can be measured with this power meter. Several circuits can be used to extend the range including the familiar attenuator. Perhaps the simplest is a resistive tap, shown in Figure 3. This circuit consists of a flat piece of metal, L1, soldered between coaxial connectors J1 and J2, allowing a transmitter to drive a 50-Ω termination. A resistor, R1, taps the path to route a sample of the signal to J3, which connects to the power meter. R2 shunts J3, guaranteeing a 50-Ω output impedance. Selecting the values that comprise R1 establishes the attenuation level.

[1]Notes appear on page 43.

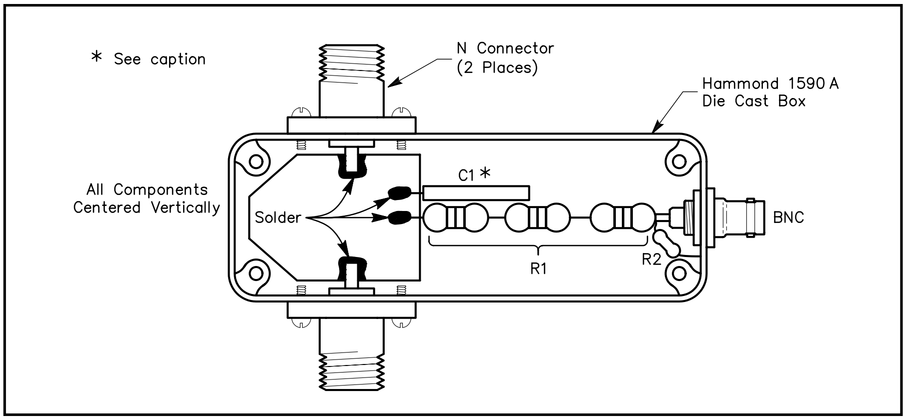


Figure 4—Drawing of the 40-dB power tap assembly shown schematically in Figure 3. The center conductors of the two N connectors (RF INPUT and RF OUTPUT) are connected by a 1×1¹/₂-inch piece of sheet brass with its corners removed to clear the pillars in the Hammond 1590A die-cast aluminum enclosure. C1 is made from a piece of #22 AWG insulated hook-up wire; it extends 0.6 inch beyond the edge of the tinned metal piece and almost rests against the two resistor bodies.

The tap extends the nominal +10 dBm power meter maximum level to +50 dBm, or 100 W. Power dissipation becomes an issue at this level, so R1 is built from three series-connected half-watt, carbon-film resistors.

The tap is built with the J1 to J2 connection configured as a 50-Ω transmission line as shown in Figure 4 and the accompanying photographs. Adjustments were performed with an HP-8714B network analyzer. The analyzer was used to adjust the value of C for an attenuated path to J3 that is flat within 0.1 dB up to 500 MHz. The tap can then be used with a spectrum analyzer or laboratory grade power meter.

It is not realistic to achieve 0.1-dB accuracy through UHF without a network analyzer for adjustment. However, if the tap is duplicated using the mechanical arrangement of Figure 4, you can expect the tap to be flat within about 1 dB through 500 MHz. The low-frequency attenuation is determined merely by the resistors, so can be guaranteed with DVM measurements. If the primary interest is in measurements below 150 MHz, you can replace the N connectors with BNC connectors. The tap is housed in a Hammond 1590A box.

Calibration

We read and use our meters in one of two ways. The DVM output is recorded and used with an equation that provides power in dBm. Alternatively, we read the panel meter and look at a chart taped to the back of the instrument. In both cases, we need a known source of RF power to calibrate the tool.

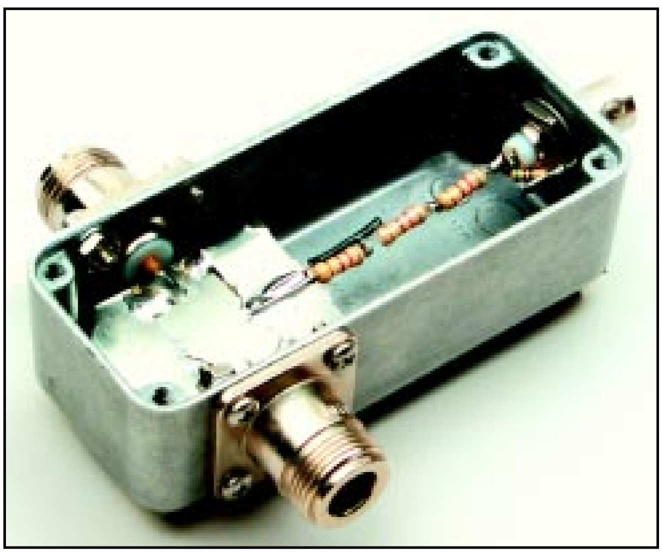
The easiest way to calibrate this instrument is with a calibrated signal generator. Set the generator for a well-defined output and apply it to the power meter. We did our calibration work at 10 MHz and levels of –20 and –30 dBm. The two levels provide a 10-dB difference that establishes the slope in decibels per DVM millivolt. One of the two values then provides the needed constant for an equation. The signal generator can be stepped through the amplitude range in 5- or 10-dB steps to generate data for the meter plot. Figure 5 shows a plot of DVM output Vs power meter reading. The meter plot is similar.

If you don't have access to a quality signal generator, you can calibrate the power meter using a low-power transmitter. A power level of 1 to 2 W at 7 MHz is fine. Attach the transmitter through the tap to a dummy load where the output voltage can be read directly using a diode detector and DVM as shown in Figure 6. If the power output is 1 W, the peak RF voltage will be 10 V. The detector output will then be about 9.5 V and the signal to the power meter is –10 dBm. Adding a 10-dB pad, as shown in Figure 6, at the meter input drops the power to –20 dBm for the second calibration point.

Applications

There are dozens of applications for this little power meter, a few of which are shown in the accompanying figures. Some applications are obvious and practical while others are more elaborate and instructive. Most of these measurements are *substitutional*, where the power meter is substituted for a load in a circuit. In contrast, most measurements with an oscilloscope are *in situ*, performed *in place* within a working circuit.

Figure 7A shows power measurement for early stages of a transmitter, very low power transmitters, or signals from other



An inside view of the simple attenuator shown in Figure 3.

The calibration curve taped to the back of the instrument provides output readings in dBm relative to the meter's 0 to 15 V scale.

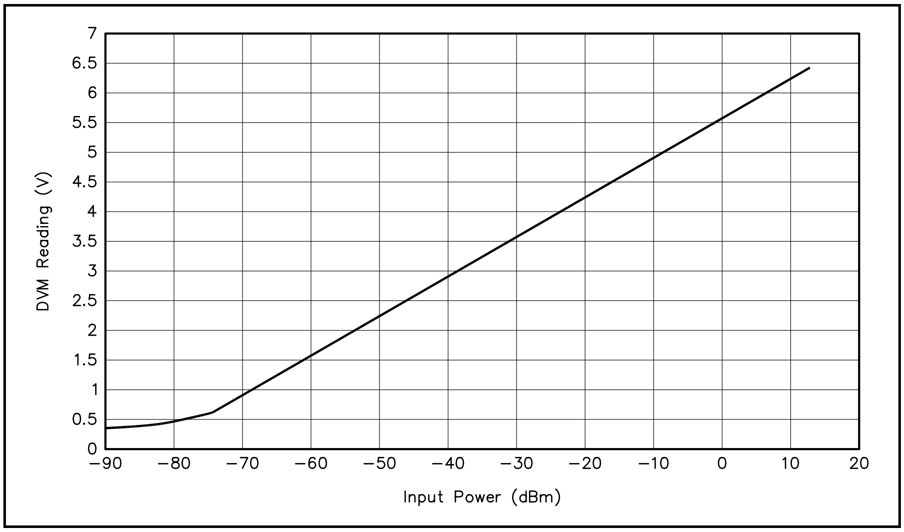


Figure 5—Plot of the DVM output versus generator power.

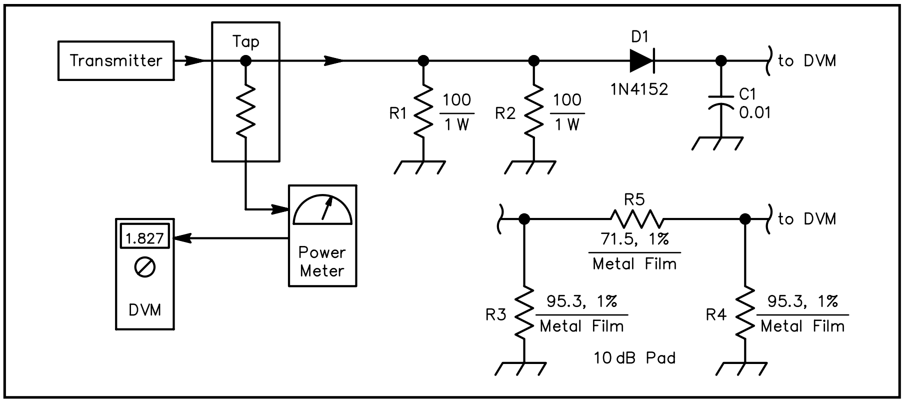


Figure 6—If a signal generator is not available, calibration can be done using a low-power transmitter. Resistor values for a 10-dB pad are shown.

C1—0.01 µF disc ceramic
D1—1N4152
R1, R2—100 Ω, 1 W
R3, R4—95.3 Ω, 1% metal film
R5—71.5 Ω, 1% metal film

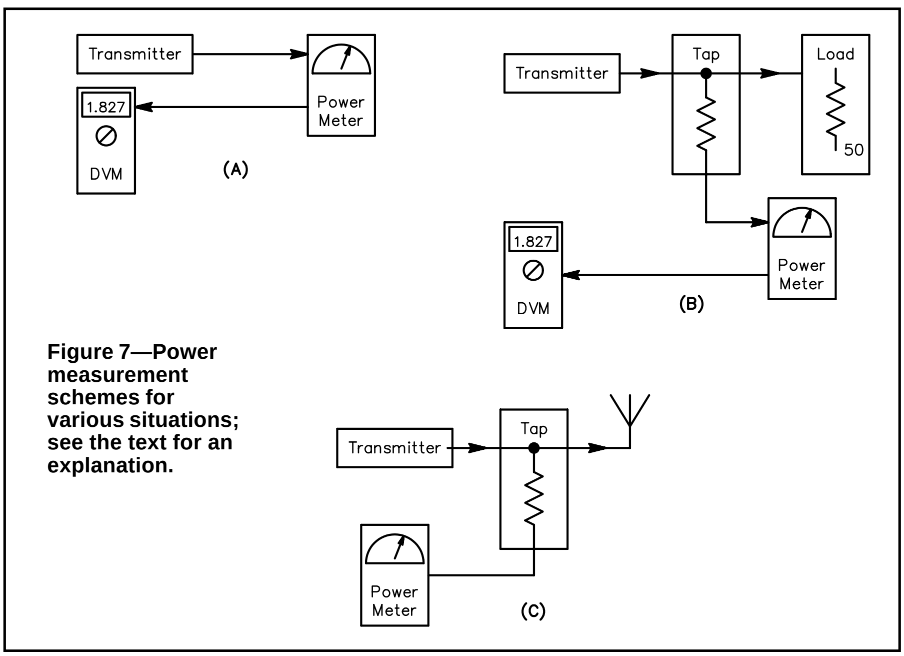


Figure 7—Power measurement schemes for various situations; see the text for an explanation.

sources. Among the most common is measurement of the power available from a LO system that will then drive a diode-ring mixer. The nominal maximum power for the meter is +13 to +16 dBm. We were able to perform measurements nearly up to +18 dBm at HF, but this is not maintained at the VHF. Careful calibration at HF was made by comparing our meters' outputs to those of an HP435A.

The tap of Figure 3 extends transmitter testing with the setup of Figure 7B. A good dummy load (termination) is placed on the tap output with the transmitter attached to the input. The power in dBm is now that read on the meter in dBm plus the tap attenuation in decibels.

We sometimes wish to measure power during an operating session. This can be done with the setup of Figure 7C. A typical application might be a QRP station where the operator experiments with significantly reduced, but variable power.

The power meter is useful for a variety of applications with bridge circuits. Figure 8 shows the meter as the detector for a return loss bridge (RLB) driven by a signal generator.[5] In this example, we use the system to adjust an antenna tuner. Because of the excellent sensitivity of the power meter, the generator need not have high output power. For example, we often make these measurements with a homebrew generator delivering +3 to +10 dBm.

The use of such low power can complicate the measurements, as we discovered when we tried the experiment of Figure 8. The exercise began without either of the filters shown. When the generator was turned on, the power meter indicated –4 dBm from the RLB. We tuned the matching circuit, but could only achieve –25 dBm, indicating 21-dB return loss.[6] No further improvement could be observed. This was the result of local VHF TV and FM broadcast interference. A bandpass or low-pass filter in the power-meter input eliminated the residual response, allowing us to achieve a 45-dB return loss with further tuning. But this was also a limit where no further improvement seemed possible. Adding a low-pass filter to the signal generator output reduced the harmonics there, allowing further improvement. We were eventually able to tune the system for an absurd 60-dB return loss (SWR = 1.002), generally impossible to measure with normal bridges using diode detectors.

The power meter is ideal for experiments with various RF filters as shown in Figure 9. A signal generator is attached to the filter input with the power meter terminating the output. The filter may then be tuned or swept. Temporarily re-

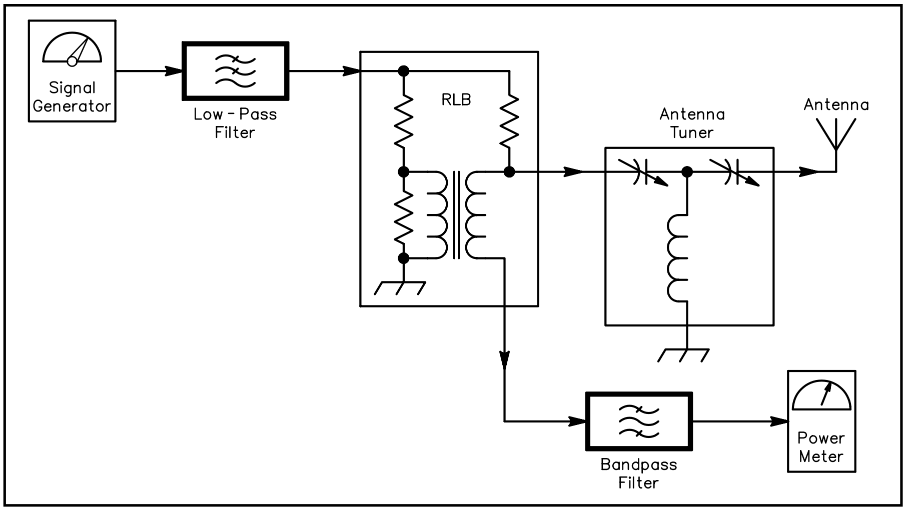


Figure 8—Using the power meter for bridge measurements.

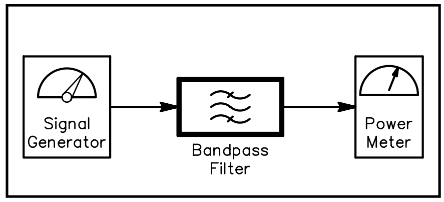


Figure 9—Filter measurements with the power meter.

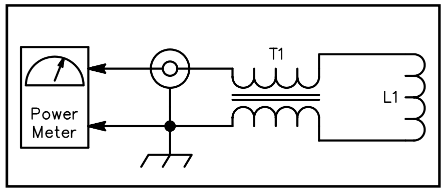


Figure 11—An RF sniffer probe that allows observation of relative RF levels. This probe allows you to see self-oscillation in amplifiers, or proportional responses in a receiver or transmitter.
L1—Two turns of insulated wire, 1/4-inch ID.
T1—Several ferrite beads on a length of coaxial cable; see text.

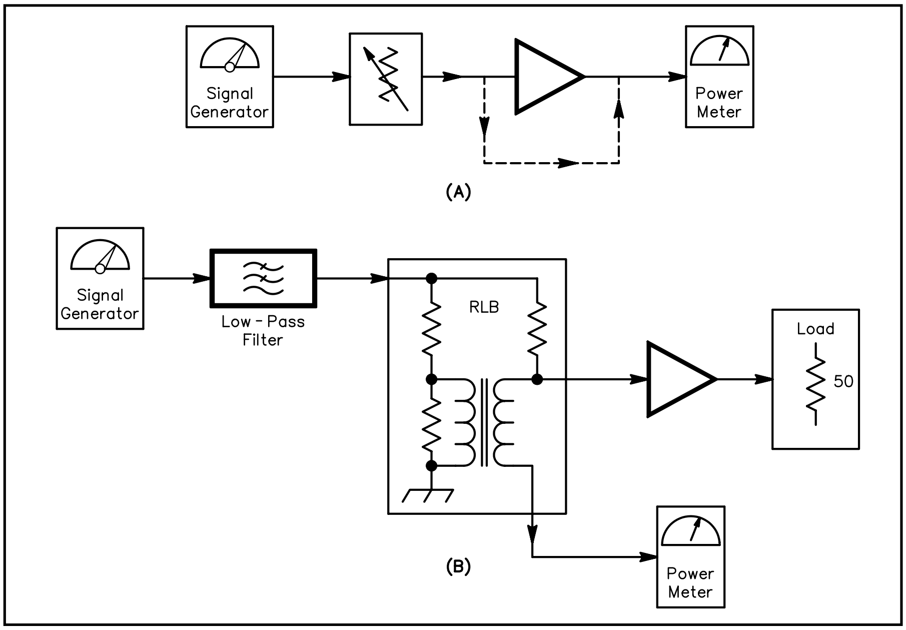


Figure 10—Amplifier measurements with the power meter. At A, making gain measurements. At B, a method to determine the input-impedance match. Reversing the amplifier terminals allows investigating reverse gain and output match.

placing the filter with a coaxial through connection allows you to evaluate filter insertion loss. Both the power meter and the signal generator are 50-Ω instruments, so the filter will need matching networks if it is not a 50-Ω design.

As with the previous example, measurement anomalies can be observed when investigating filters. For example, after using the power meter to adjust a 7-MHz bandpass filter we were able to easily measure the second-harmonic content of the signal generator when tuned to 3.5 MHz.

Figure 10A shows the power meter used with a signal generator to study amplifier circuits. A step attenuator is shown with the generator, allowing the power level to be reduced while preserving a 50-Ω environment. Generally, a drive level of –30 dBm is low enough with typical circuits. The system is initially set up with a through connection, indicated by the dotted line. Then the amplifier is inserted and the output power is measured. The difference between the two responses, each in dBm, is the gain in decibels. An interesting and easily performed related measurement is that of amplifier reverse gain. Merely swap the amplifier terminals, attaching the generator to the *output* and the power meter to the *input*. The measured *gain* will now be a negative decibel number.

Amplifier investigation continues with the setup of Figure 10B where we use an RLB to measure the input impedance match. Although a simple bridge will not provide the actual input impedance, it will tell you how close the circuit is to a perfect match. Adjustments can be done to achieve a match. Again, reversing the amplifier allows examining the output. We included a low-pass filter in the generator output, a precaution that may also be useful with the gain-determination setup. The measurements of Figure 10 provide the information normally provided by a scalar network analyzer.

The power meter can serve as the detector for a number of simple instruments. Figure 11 shows a simple RF sniffer probe, handy for examining circuit operation. The probe consists of a small inductor attached to the end of a piece of coaxial cable (RG-58, RG-174, or similar). A few ferrite beads of about any type are placed over the outside of the cable near the coil. The probe can be placed close to an operating circuit to look for RF. The smaller the link diameter, the greater the spatial resolution can be. This is a scheme that actually lets you see self-oscillation in an amplifier, much more useful than a speculation that a circuit "might be oscillating."

The power meter can be used with other probes. One might be a simple antenna that would allow field-strength determinations. Another is a resonance-indicating probe that would provide traditional dip meter-like measurements, but with improved ac-

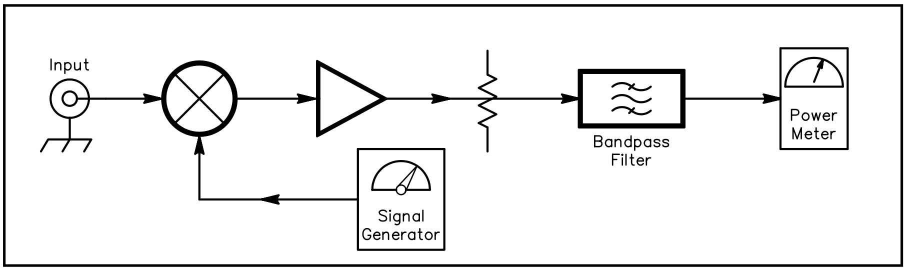


Figure 12—Adding a few components to a signal generator and the power meter creates a measurement receiver. The kinds of measurements possible depend on the filter used. See the text for some possibilities.

An inside view of the wattmeter showing its "dead-bug" construction and simplicity.

This version of the power meter is built in an inexpensive RadioShack utility box.

curacy and sensitivity.[7]

A recent *QST* project developed by Rick Littlefield, K1BQT, uses an AD8307 as a relative RF indicator.[8] That instrument, with the probe described in the sidebar by Ed Hare, W1RFI, is aimed at examining conducted electromagnetic interference (EMI). Our power meter should function well with that probe. There is great potential for small portable instruments for the study of both conducted and radiated EMI.

Figure 12 shows an example of some simple instruments that can be built using the power meter as a foundation. Here, the signal generator becomes the LO for a mixer such as the popular diode ring. This drives an optional amplifier and attenuator, followed by a bandpass filter. The power meter measures the filter output. The result is a custom measurement receiver.

We have built two variations of this project. The first uses a three-resonator LC bandpass filter tuned to 110 MHz, while the signal generator tunes from 50 to 250 MHz.[9] A Mini-Circuits MAV-11 is used for the amplifier. The resulting receiver can then be used to measure signals over the entire spectrum up to 360 MHz with sufficient resolution to examine transmitter spurious responses.

The second measurement receiver uses a homebrew 5-MHz crystal filter with a 250-Hz bandwidth. The signal generator is a homebrew unit with extreme tuning resolution, or bandspread. This instrument was used to measure SSB-transmitter carrier and sideband suppression and IMD, and for examining spurious output of experimental frequency synthesizers.

Concluding Thoughts

The traditional view of a power meter is as an instrument that examines transmitter output. But it can be much more than that. The AD8307 allows you to build a power meter that turns a common Amateur Radio station into the beginnings of a RF measurement lab.

Our thanks to Barrie Gilbert of Analog Devices Northwest Labs for providing the AD3807 IC samples.

Notes

[1]**www.analog.com**. The data sheet includes an extensive discussion of the theory of operation of the logarithmic detector and applications beyond the scope of this article.

[2]Kanga US offers a collection of most of the parts for this project, excluding the meter, copper-clad board and enclosure. For specifics, contact KANGA US, Bill Kelsey, N8ET, 3521 Spring Lake Dr, Findlay, OH 45840; tel 419-423-4604; **kanga@bright.net**; **www.bright.net/~kanga/**.

[3]$P_{mW} = 10^{dBm/10}$

[4]Feedthrough capacitors are available from Down East Microwave Inc, 954 Rt 519, Frenchtown, NJ 08825; tel 908-996-3584, fax 908-996-3702; **www.downeastmicrowave.com/**.

[5]See Wes Hayward, W7ZOI, and Doug DeMaw, W1FB, "Solid-State Design for the Radio Amateur," p 154, ARRL, 1977. Directional couplers are also useful in this application, such as that used in the classic W7EL power meter, Roy Lewallen, W7EL, "A Simple and Accurate QRP Directional Wattmeter," *QST*, Feb 1990, pp 19-23 and 36.

[6]A return loss of 21 dB corresponds to a SWR of 1.196, already a great match for most practical antenna situations.

[7]See Wes Hayward, W7ZOI, "Beyond the Dipper," *QST*, May, 1986, pp 14-20. Also, the signal-generating portion of that instrument is useful as a simple, general-purpose RF source.

[8]Rick Littlefield, K1BQT, "A Wide-Range RF-Survey Meter," *QST*, Aug 2000, pp 42-44; see also Feedback, Oct 2000, p 53.

[9]Wes Hayward, W7ZOI, "Extending the Double-Tuned Circuit to Three Resonators," *QEX*, Mar/Apr 1998, pp 41-46. The band-pass filter was then used in the instrument described in Wes Hayward, W7ZOI, and Terry White, K7TAU, "A Spectrum Analyzer for the Radio Amateur," *QST*, Aug 1998, pp 35-43; —Part 2, Sep 1998, pp 37-40.

Over the years, Wes Hayward, W7ZOI, has provided readers of QST, The ARRL Handbook and other ARRL publications with a wealth of projects and technological know-how. His most recent article, The Micro-mountaineer Revisited (which he wrote with K7TAU), appeared in July 2000 QST. You can contact Wes at 7700 SW Danielle Ave, Beaverton, OR 97008; **w7zoi@easystreet.com**.

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