

An In-Line Spectrum Analyzer Station Interface

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Introduction

With the availability of low-cost, high performance spectrum analyzers^{1,2,3,4}, it now becomes possible to provide spectral station monitoring of both transmit and receive band signals at a reasonable price. In particular, at \$700 the Rigol DSA705 spectrum analyzer is comparable in price to some high-end power meters. You can use a coupler with a high coupling factor or a high-power attenuator to measure your transmit spectrum. And you can connect the spectrum analyzer directly to the transmission line to look at band activity. But wouldn't it be nice if you could easily monitor either your transmit spectrum or receive-band activity without having to reconfigure your system?

Protection Requirements

My objective was to provide an in-line spectrum analyzer interface for transmit and receive monitoring, while also protecting the spectrum analyzer under all conditions that could possibly damage it. These conditions include damage from the transceiver's high RF signal level, the close proximity of a high power transmitter on a nearby antenna, static build-up on the connected antenna and transmission line, and interface failure modes due to connectivity errors or even component failures.

Most spectrum analyzers have about a +20dBm (100 milliwatt) maximum input power rating above which damage can occur. A 100-watt transmitter is +50dBm, so at least 30dB of protection is needed for the spectrum analyzer front-end when transmitting. I felt that a goal should be at least 50dB isolation to ensure that the signal is low enough so spectrum analyzer front-end overload doesn't cause a false transmit signal display. And I wanted to easily remove most of this attenuation for receive monitoring.

Spectrum Analyzer/Transceiver Protection Technique

My spectrum analyzer in-line interface solution is shown in Figure 1. An Omron G6A-274P40-DC12 DPDT signal relay, enabled by the transceiver's amp-key output, disconnects the spectrum analyzer from the antenna and shorts the spectrum analyzer input when transmitting. This relay has an operational life of 100 million operations and switches in less than 5ms (3ms typical) so it is QSK-compatible⁵. In my original QST article I called out a GF710 lamp/fuse to further protect the spectrum analyzer input should something go wrong and the transmitter is keyed without switching out the protection circuit. However, cartridge lamps are becoming obsolete. You can substitute GF540 or GF780 lamp/fuses if you can find them. Or you can use a 125ma fast-blow fuse - a 3AG125. I prefer the lamps as fuses as when they heat up they present a high impedance before they blow for even more protection. The lamp or fuse snaps into ¼-inch fuse clips and is easily replaced should it burn out. When receiving, two sets of back-to-back diodes limit any external high-level RF signal at the spectrum analyzer input. Typically 1N4454 (or similar) switching diodes provide receiver front-end limiting at about +10dBm. However higher current diodes were needed to ensure that the lamp/fuse would open if necessary, and I found that 1N4003 diodes limit well at about +17dBm from 1.8-54 MHz. A series 100 ohm resistor followed by a pair of back-to-back 1N5711 shottky diodes further limits a high level signal to about 0dBm at the spectrum analyzer input. Finally, a 47K resistor continuously bleeds any static

build-up on the transmission line, and the two 10pf capacitors compensate for wiring and relay inductance.

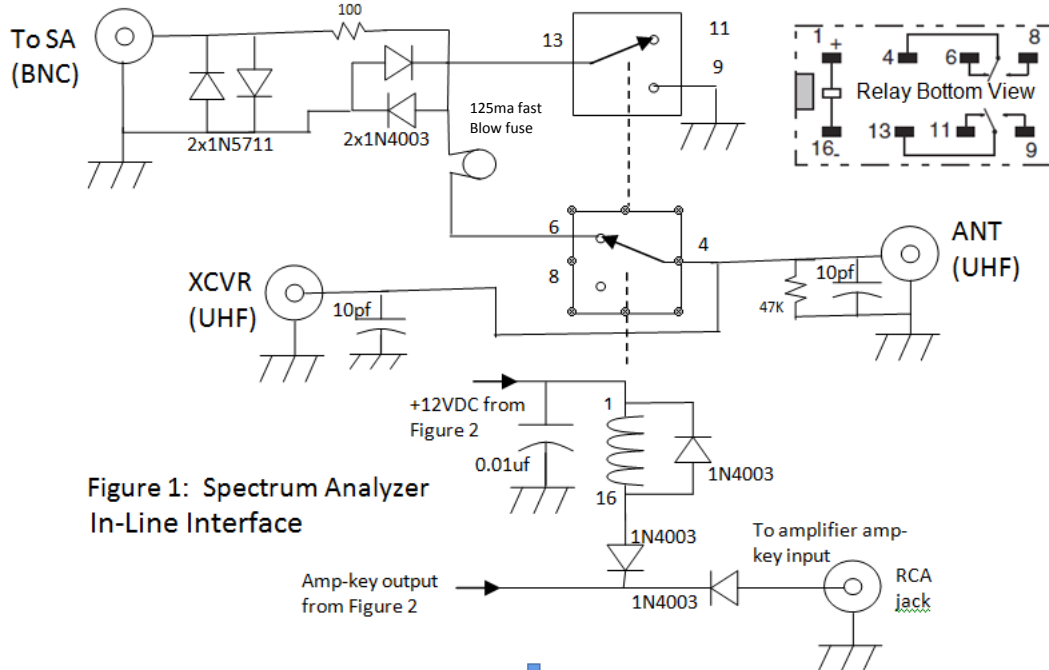


Figure 1: Spectrum Analyzer In-Line Interface

Figure 2 shows the buffer/keying portion of the circuit. It provides an open circuit voltage less than 8VDC, and requires a key-down current less than 2-millamps thus permitting it to interface with any transceiver's amp-key output. And this circuit will key any amplifier with an open circuit keying voltage of up to +80VDC and a keying current of up to 500ma. Finally, the series 4.7K resistor and 0.33uf capacitor extends the relay turn-off delay to about 10ms for those transceivers that prematurely un-key the amplifier⁶. The complete parts list for Figures 1 and 2 is given in Table 1.

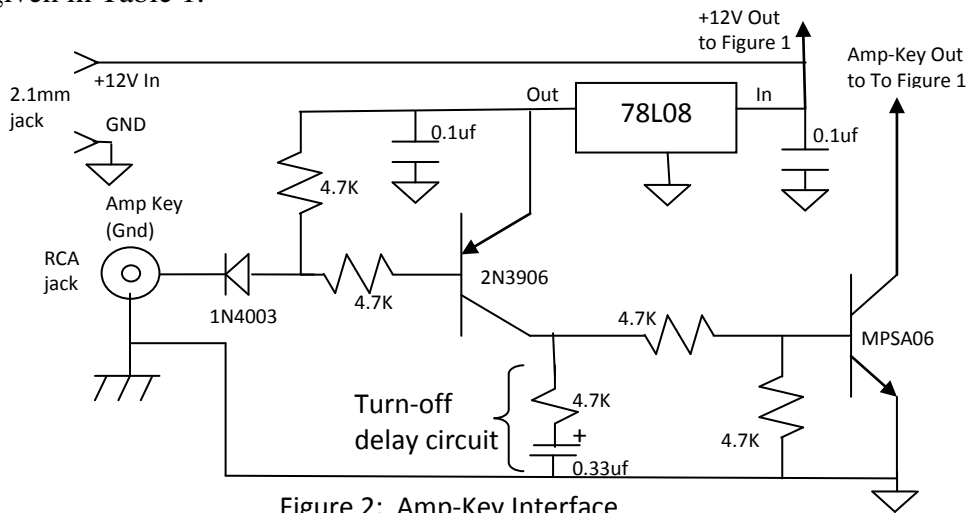


Figure 2: Amp-Key Interface

Table 1: Figure 1 Spectrum Analyzer In-Line Interface parts list

<u>QTY</u>	<u>Description</u>	<u>Mouser part number</u>	<u>Price each</u>
6	1N4003 silicon diode	863-1N4003G	\$0.18
2	1N5711 shottky diode	511-1N5711	\$0.45
2	10pf 1KV capacitor	594-S100K25SL0N63L6R	\$0.15
2	RCA jack	502-3501FPX	\$1.49
1	BNC jack	571-5-1634523-1	\$1.17
1	2.1x5.5mm DC jack	163-1060-EX	\$1.35
1	DPDT signal relay	653-G6A-274P40-DC12	\$4.63
1	16 pin DIP socket (machine pin)	535-16-3518-10	\$1.75
1	125ma fast blow fuse	530-3AG125-R	\$0.29
Or 1	GF710	560-GF710	\$1.05
Or 1	GF540	560-GF540	\$1.03
Or 1	GF780	560-GF780	\$4.00
1	Project Box 3.5x2.125x1.625	537-TF-773	\$5.89
4	Rubber Feet	517-SJ-5003BK	\$0.11
2	UHF connector	601-25-7350	\$2.03
2	#4 solder lugs	534-7325	\$0.23
1	0.33uf elec. Capacitor	647-UVZ1HR33MDD	\$0.28
3	0.1uf 100V capacitor	581-SR211C104KARTR1	\$0.11
1	MPSA06 transistor	512-MPSA06	\$0.42
1	78L08 regulator	863-MC78L08ACPG	\$0.44
1	2N3906 PNP Transistor	512-2N3906TA	\$0.19
1	100 ohm resistor	603-MFR-25FRF52100R	\$0.10
5	4.7K resistor	660-MF1/4LCT52R472J	\$0.10
1	47K resistor	660-MF1/4LCT52R473J	\$0.10
2	0.25" long #4 threaded stand-off	636-160-000-006R032	\$0.26
2	Fuse Clips, PC mount	576-01020074Z	\$0.20
4-5"	RG174 coax		
2	4-40 x 9/16" screws, nuts and split lockwashers for pcb mounting		
4	4-40x3/8" screws, nuts and split lockwashers for UHF connector mounting		
1	PC Board if desired		

While everything can be built on a perf-board, a printed circuit board makes assembly much easier due to the number of components. For those who wish to go this route, I have a few prototype pc boards available, or I will be happy to provide the EXPRESSPCB layout. Figure 3 shows my printed circuit board component locations.

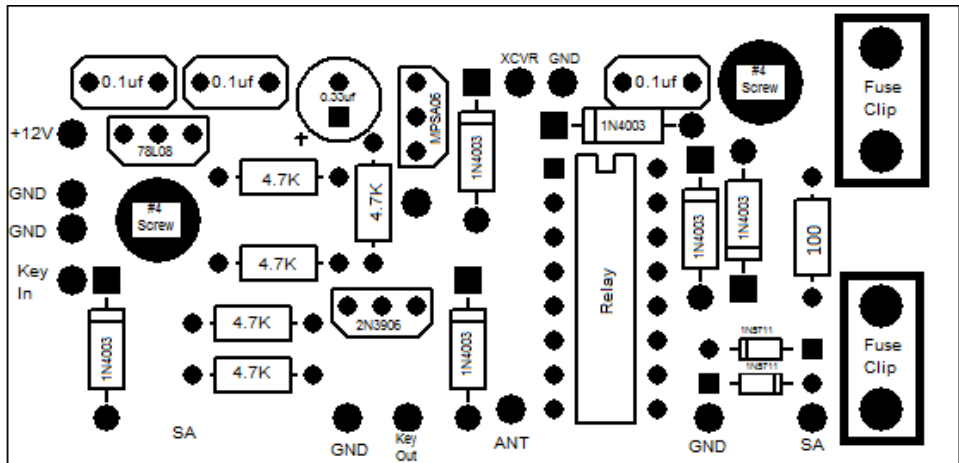


Figure 3: Component locator for the printed circuit board assembly

The 10pf compensating capacitors are soldered across the input and output UHF connectors to solder-lug grounds, and the 47K resistor is soldered across the output UHF connector to ground. Figure 4 is an internal view of the completed unit. RG-174 coax is used on the spectrum analyzer and transceiver output ports to keep isolation as high as possible. Figures 5 and 6 show the input and output connectors. Labeling was done with Casio black-on-clear labels.

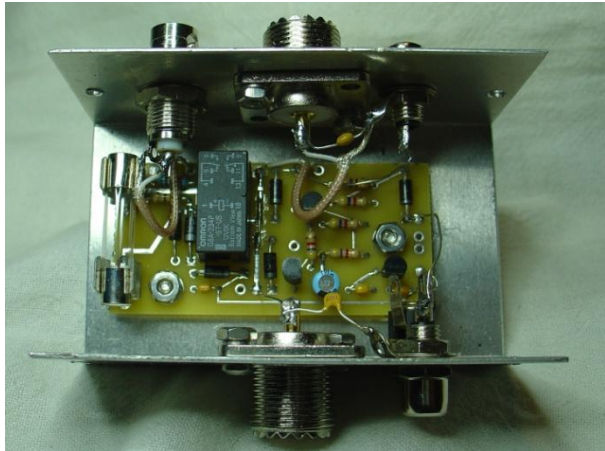


Figure 4: Internal view



Figure 5: Transceiver side



Figure 6: Antenna side

Now for the all-important performance measurements. First, Figure 7 shows the transmit path return loss and insertion loss. The worst-case insertion loss is 0.03dB on 6-meters, and return loss is 23dB on 6 meters (SWR<1.15:1).

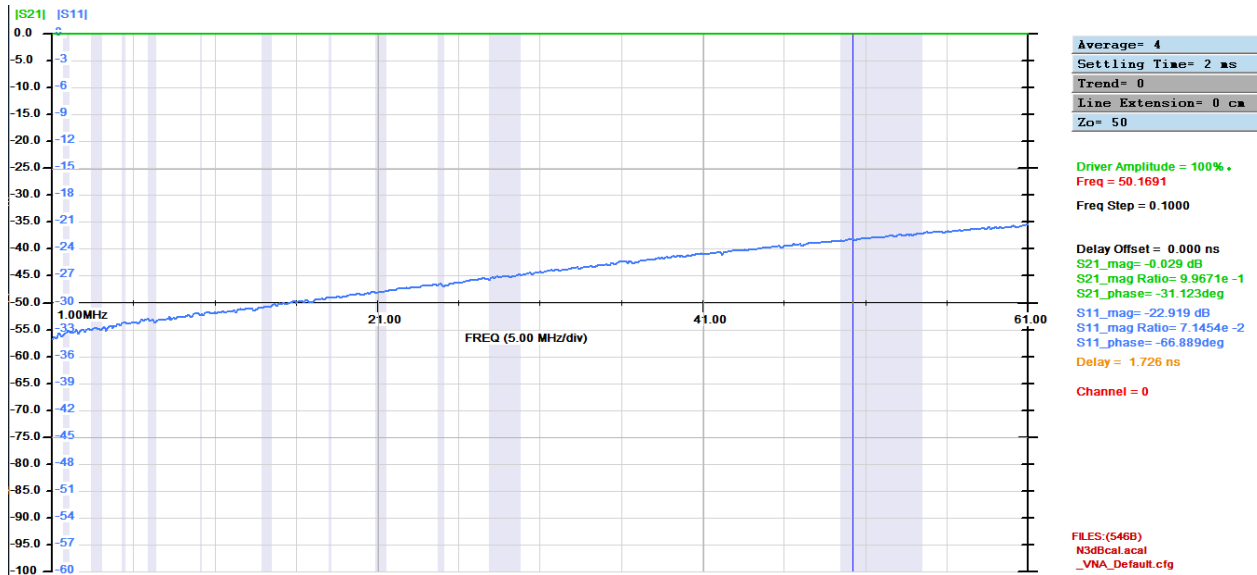


Figure 7: Transmit path SWR and insertion loss

The important transmit-to-spectrum analyzer isolation is shown in Figure 8. Note that the worst case isolation of 52dB occurs on 6 meters, ensuring a maximum spectrum analyzer input level less than 0dBm for a 100-watt transmitter.

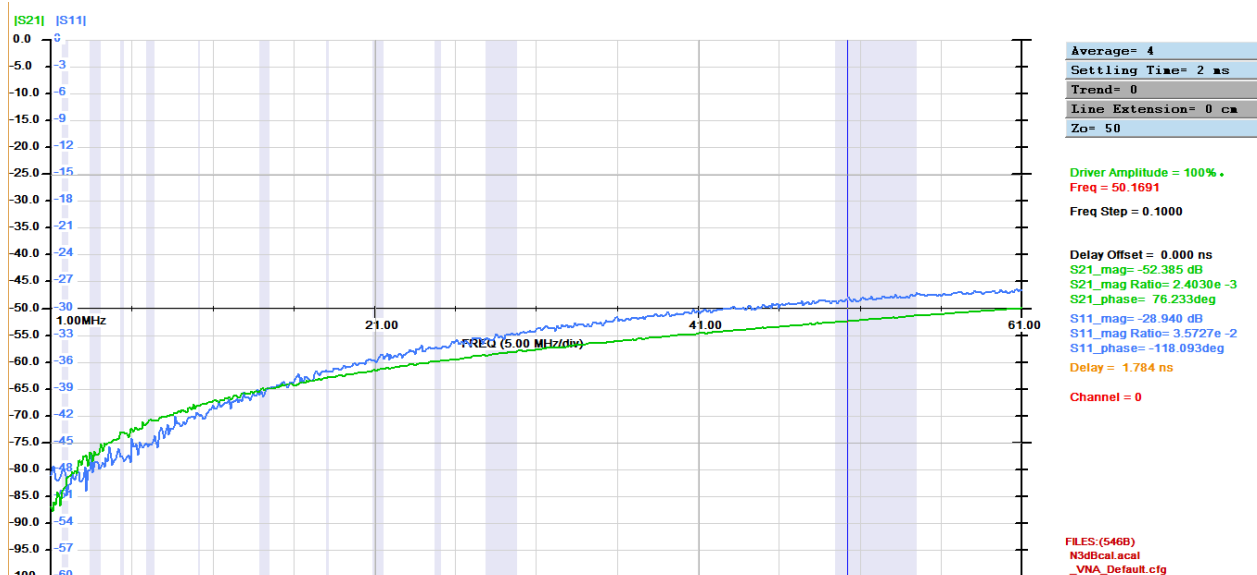


Figure 8: Transmit-to-spectrum analyzer isolation

During receive, the receive-to-spectrum analyzer insertion loss is about 11dB as shown in Figure 9, resulting in a spectrum analyzer threshold reduction of 11dB. As modern spectrum analyzers have a typical threshold of -130dBm, this still permits monitoring receive signals as low as about

S1. Also, during receive the transceiver's threshold is degraded by about 2dB below 30MHz, and about 3dB on 6-meters due to the parallel termination of the spectrum analyzer interface circuitry.

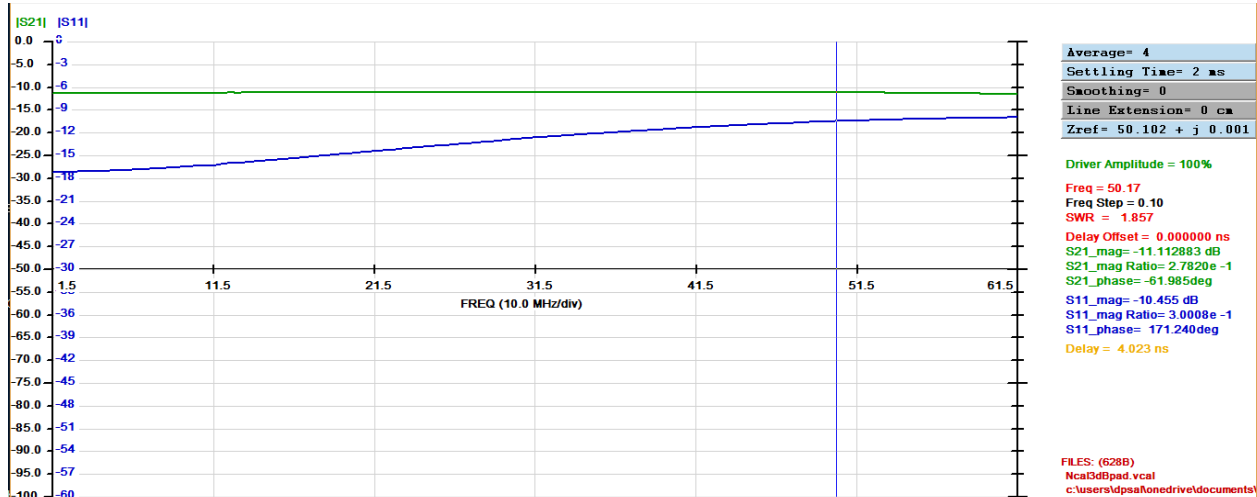


Figure 9: Receive-to-Spectrum Analyzer loss

Connecting the Spectrum Analyzer In-Line Interface

The spectrum analyzer in-line interface connects between the transceiver's RF output and the antenna or amplifier (if used). The transceiver's amp-key output plugs into the amp-key IN on the spectrum analyzer interface. If an amplifier is used, the spectrum analyzer interface RF output feeds the amplifier's RF input, and an amp-key cable connects from the spectrum analyzer interface's amp-key OUT to the amplifier's amp-key input. Figure 10 shows the interface wiring.

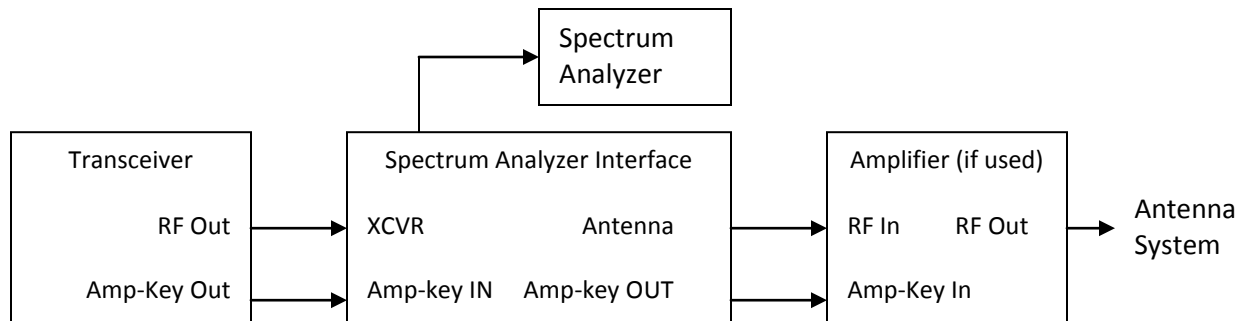


Figure 10: Spectrum Analyzer In-Line Interface Connection Block Diagram

Some Real-World Testing

I tested the spectrum analyzer in-line interface with my IC-706MKIIG transceiver (which has the premature un-key issue) and Siglent SSA3021X spectrum analyzer. The dynamic range difference between transmit and receive does require changing spectrum analyzer parameters depending on whether you want to monitor your transmit signal or monitor the receive spectrum. However, this just takes a few seconds – especially since you can just tap PEAK on some spectrum analyzers to automatically set the correct sense levels.

I also verified that the spectrum analyzer would not be damaged should one fail to connect the amp-key cable or DC power to the protector, or if something failed in the interface that prevented the relay from operating. In these cases, keying the IC-706MKIIG resulted in a momentary flash of the lamp as it burned out. No damage occurred to the 1N4003 diodes, the 100 ohm resistor, the 1N5711 diodes, or the spectrum analyzer. And while there is undoubtedly a momentary high SWR due to the lamp/diodes in shunt with the RF output, the lamp burned out so fast that no transceiver ALC kick or power turn-down was observed.

Conclusion

I've described an in-line interface for those who wish to use a spectrum analyzer for both transmit and receive signal monitoring. This unit will work with any transceiver that has an amp-key output, and it will even operate under full break-in CW conditions.

¹Bob Allison WB1GCM, Product Review, "Rigol Technologies DSA815-TG Spectrum Analyzer", QST February 2013, pp. 55-58.

²Phil Salas AD5X, Product Review, "Signal Hound USB-SA44B 4.4 GHz Spectrum Analyzer and USB-TG44A Tracking Generator", QST February 2016, p. 58.

³Phil Salas AD5X, Product Review, "Siglent SSA3021X Spectrum Analyzer", QST November 2016, pp. 63-66.

⁴Phil Salas AD5X, Product Review, "Rigol DSA705 Spectrum Analyzer", QST July 2017, pp. 41-44.

⁵Phil Salas AD5X, "Low Cost QSK Conversion for the Ameritron ALS-600 HF Amplifier", QST June 2009, pp. 47-49

⁶Phil Salas AD5X, "Internal Full Break-in Keying Interface for the ALS-600 Amplifier", QST November 2011, pp. 42-44.