Theoretical Analysis of the HPSDR ALEX Power Sense Circuit

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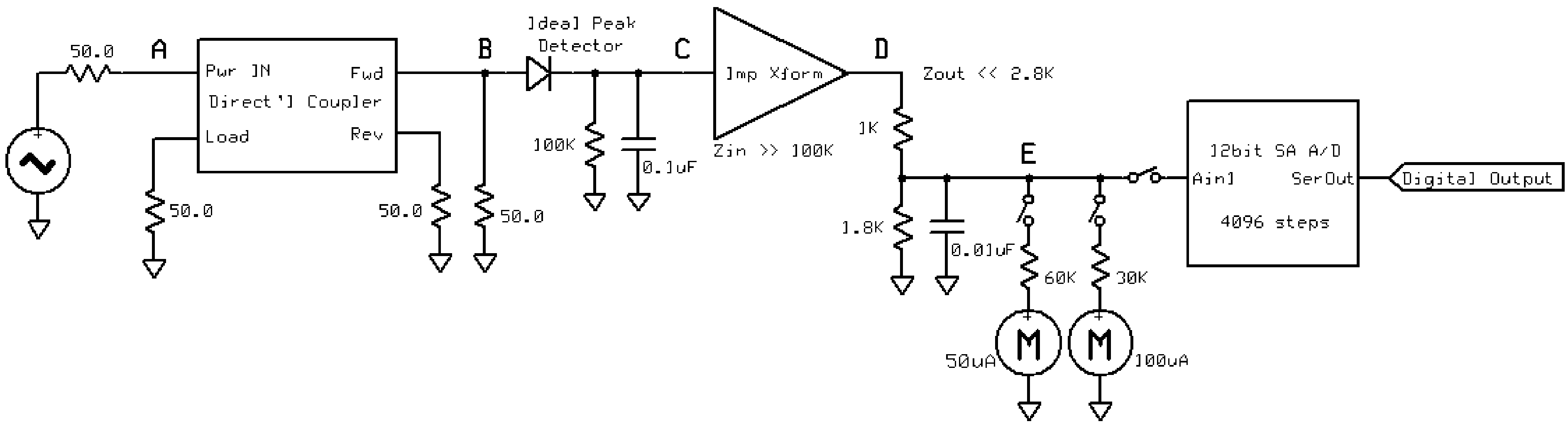
Below is a simplified diagram of the Alex circuit.



What do we know for sure:

1. The Actual Schematic and Parts List.
2. The specified output is to be from 0 to 3V [Implied is that a 0 to 100 Watt amplifier like Munin may be used].
3. In Hermes:
   a) U17 ADC70H90C1MT 12 bit Successive Approximation Analog to Digital converter [4096 counts] appears to be CMOS
   b) pin 4 FWD_PWR input through FL11 and Zero Ohm R88
   c) Pin 5 REV_PWR input through FL10 and Zero Ohm R84
   d) Dout = pin 15 ADCMISO to pin 57 U9B
   e) U9B is an Altera EP3C40Q240
4. In PennyLane: - Basically the same parts, but different pin connections.
   a) U16 ADC70H90C1MT 12 bit Successive Approximation Analog to Digital converter [4096 counts]
   b) pin 4 FWD_PWR input through FL8
   c) Pin 5 REV_PWR input through FL7
   d) Dout = pin 15 ADCMISO to pin 146 U11
   e) U11 is an Altera EP2C8-PQ208
5. Hermes-Lite
   a) U13 Max11613 12 bit Successive Approximation Analog to Digital converter [4096 counts] Vref = 2.048V which limits the maximum voltage, appears to be bipolar.
   b) pin 1 Forward
   c) pin 4 Reverse
   d) pin 6 SDA [in/out] to pin32 U2E FPGA
6. Directional coupler: 20T on both Toroid’s yielding -26.03dB at the coupled port.

What are the assumptions:

1. The Directional Coupler will be terminated on all four ports with 50.0 Ohms. This is not real because SWR affects the load impedance.
2. The diode used in the peak detector is lossless and has a linear slope. This is not real because actual diodes are nonlinear with small signals and have losses.
3. The rail to rail input /output CMOS opamp [LMC6482] is configured as a non inverting follower with 0 gain and 0 phase shift. The input Zin is >> than 100K Ohms and the output Zout is << 2.8K Ohms. This circuit is primarily an impedance converter.
4. A device that is connected to point "E" does not significantly affect the current through the 1k and 1,8K ohm voltage divider.

What are the results:

CW Input power Point A	in dBm		Output of Alex Power Sensing Circuit Vdc Point E	50uA meter		100uA Meter	
250W =	53.979	dBm	5.0757	84.5956	uA	169.1911	uA
100W =	50.000	dBm	3.2103	53.5054	uA	107.0108	uA
80W =	49.031	dBm	2.8714	47.8572	uA	95.7145	uA
50W =	46.900	dBm	2.2467	37.4453	uA	74.8907	uA
40W =	46.021	dBm	2.0305	33.8413	uA	67.6827	uA
30W =	44.771	dBm	1.7583	29.3054	uA	58.6108	uA
25W =	43.970	dBm	1.6034	26.7238	uA	53.4475	uA
20W =	43.010	dBm	1.4357	23.9275	uA	47.8550	uA
10W =	40.000	dBm	1.0152	16.9199	uA	33.8398	uA
8W =	39.031	dBm	0.9080	15.1338	uA	30.2676	uA
5W =	36.990	dBm	0.7179	11.9646	uA	23.9292	uA
4W =	36.021	dBm	0.6421	10.7016	uA	21.4031	uA
3W =	34.771	dBm	0.5560	9.2672	uA	18.5344	uA
2W =	33.010	dBm	0.4540	7.5665	uA	15.1331	uA
1W =	30.000	dBm	0.3210	5.3505	uA	10.7011	uA
0.1W =	20.000	dBm	0.1015	1.6920	uA	3.3840	uA
10mW =	10.000	dBm	0.0321	0.5351	uA	1.0701	uA
1mW =	0.000	dBm	0.0102	0.1692	uA	0.3384	uA

All of the calculations can be seen and used in the spreadsheet: Perfect Theoretical analysis of Alex Directional Coupler.xls which is available..

The assumptions appear to be valid in a technical sense because the output for 100 Watts is 3.2V which is close to the specification 3V.

The chart also indicates that the output would be excessive for the Hermes-Lite above 40W, if indeed, the A/D is limited to 2.048V. Using a digital volt meter or a microamp meter would also be possible. The microamp meter should be connected to point D for better performance or a zero Ohm resistor substituted for the 1K Ohm.

Changing the number of turns on the Directional Coupler to 10 turns with 20dB insertion loss would be a better solution for the barefoot Hermes-Lite and an example of these values can be found on the second tab of the excel spreadsheet.

What are my conclusions?

The theoretical math and the assumptions appear to closely agree with the original ALEX design approach.

The circuitry and layout can be adapted to a variety of different display mechanisms by either changing the Toroid windings or changing the output attenuator resistors [1K & 1.8K in diagram] to obtain a suitable range for the desired display approach.

I have no convenient way to evaluate the SA A/D converter interpretation of the input signal as they are both dependent on the software and the FPGA configuration.

The spreadsheet will allow the easy verification of the output for various combinations of input power, toroid turns and output attenuator to fit the application.

Please remember to be cognizant of the effects of higher RF power. Resistors and toroid windings need to fit the actual application. The fact that the mathematics indicate the 250 Watt input will work, does not mean the same components that are used for a 25 Watt unit will function at the higher level.