Xpol

Test Results Document

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Prepared for

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Submitted by

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A. X-band Transceiver

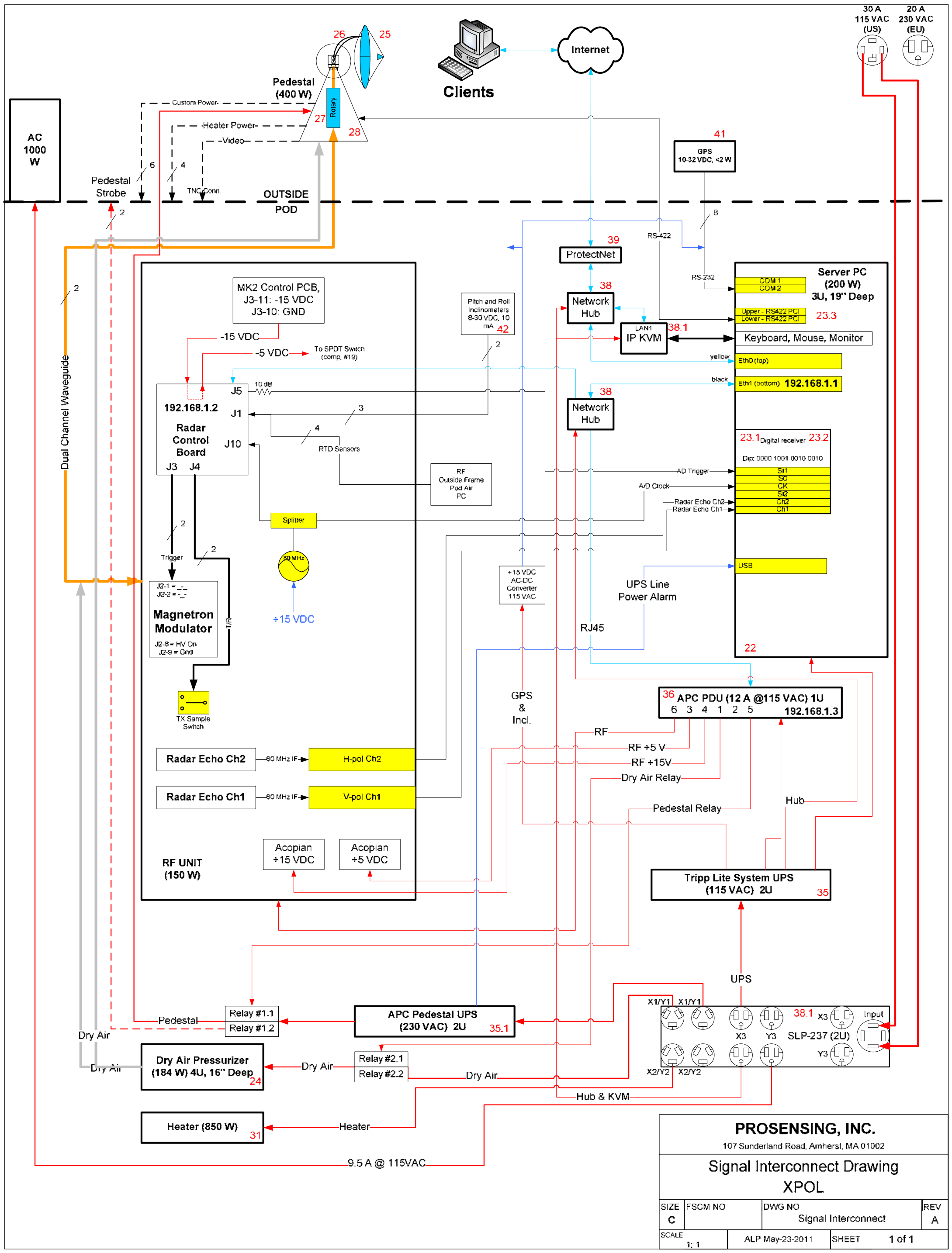

Figure 1. Xpol Interconnect Diagram

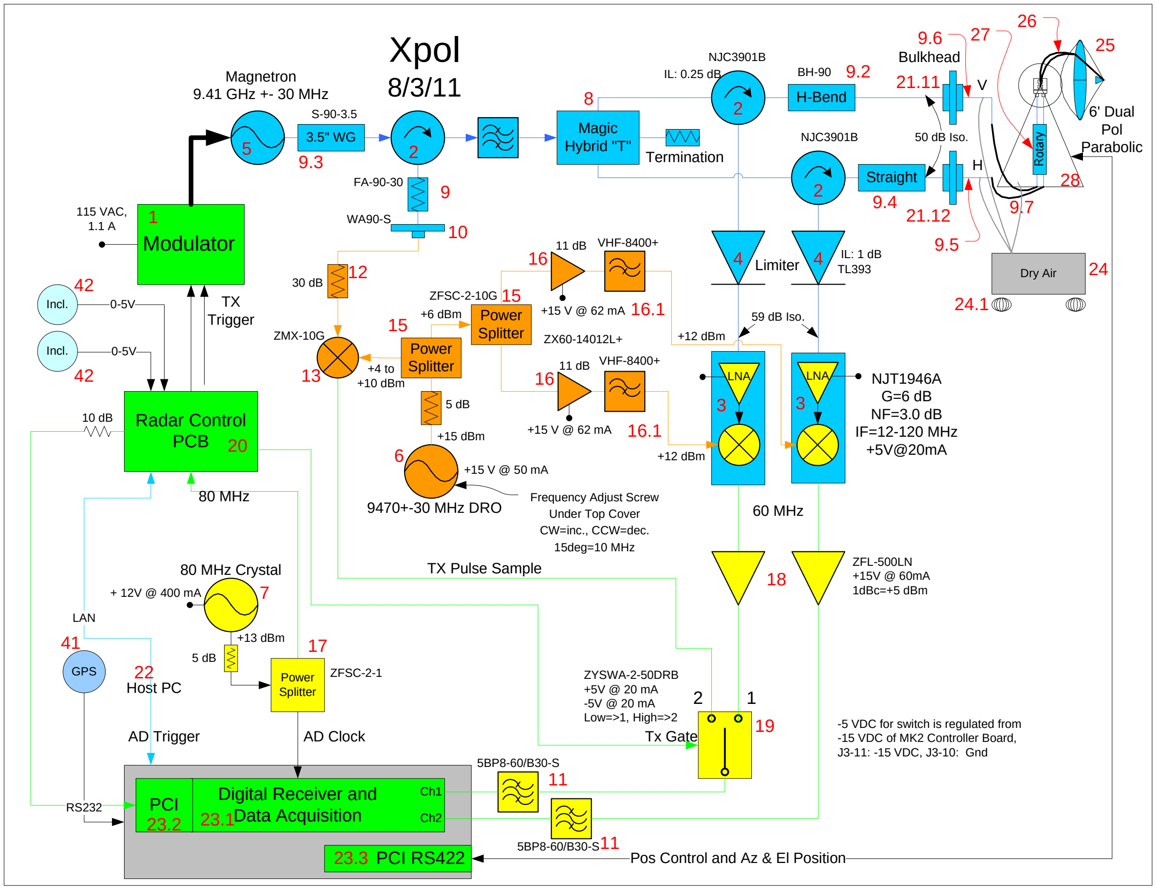

Figure 2. The ProSensing Xpol radar transceiver component level block diagram.

Table 1. Xpol component list.

1	25 kW Transmitter	Klein Navigation	8566
1.1	X-band Magnetron NJR (replacement)	Richardson El	M1458A
2	X-band circulator	Richardson El	NJC3901B
3	X-band front-end	Richardson El	NJT1946A
3.1	Coax LO line	East Coast Mic.	
4	X-band limiter	Richardson El	TL393
6	X-band LO Oscillator	Princeton	PmT_1240-9.47
7	80 MHz Crystal	Wenzel	500-18332
8	X-band w.g. magic T	Dorado	HTW-90
9	X-band 30 dB waveguide atten.	Dorado	FA-90-30
9.2	X-band H-plane bend (Ch1)	Dorado	BH-90
9.3	X-band Straight WG 3.5" (Mag)	Dorado	S-90-3.5"
9.4	X-band Straight WG 5.540" (Ch2)	Dorado	S-90-5.540"
9.5	X-band Straight WG w. air nipple	MWP	105005-1016-1
9.6	X-band H-bend WG w. air nipple	MWP	105005-1016-2
9.7	X-band Twist-lex WG 1 cvr 1 chk	ATM	90-125-30-6-8
9.8	WR90 90 deg H-bend	ATM	90-510A-2X2-6-8
10	X-band waveguide to coax trans.	Dorado	WA90-S(F)
11	IF BPF Filter 60/20 MHz	Lorch	5BP8-60/B30-S
12	SMA 30 dB Attenuator	Mini Circuits	BW-S30W2
13	X-band mixer	Mini Circuits	ZMX-10GB
15	X-band splitter (2-way)	Mini Circuits	ZFSC-2-10G+
16	X-band LO Amp	Mini Circuits	ZX60-14012L+
16.1	X-band HPF	Mini Circuits	VHF-8400+
17	IF splitter	Mini Circuits	ZFSC-2-1-S+
18	IF Amp Low Noise 24 dB gain	Mini Circuits	ZFL-500LNB
19	SPDT switch	Mini Circuits	ZYSWA-2-50DRB
20	Radar Controller PCB	ProSensing	
21.11	Side Bulkhead Feedthrough	ProSensing	
21.12	Front Bulkhead Feedthrough	ProSensing	
21.2	X-band Waveguide Barcket	ProSensing	
21.3	X-band Front_end Cover	ProSensing	
21.4	Magnetron Barcket	ProSensing	
22	Host PC	Servers Direct	RDS1
23.1	Digital receiver	Echotek	ECV4-2-R105-XMC
23.2	PMC-to_PCI Adapter	Technobox	5012
23.3	2-port RS-422/485 PCI Card	Aaxeon Tech. Inc.	MSC-102B
24	Dry air pressurizer	Hutton	MT050B-81315
24.1	Aeroflex Isolators	VMC Group	CA2-125-08-T2
25	6' Dish	Seavey	AS72-9494
26	X-band Twist-flex WG 1 cvr 1 chk	ATM	90-125-48-6-8
27	Dual Channel X Rotary Joint	Kevlin	2204/3
28	Pedestal	Orbit	AL-4016
	Positioner shipping	ProSensing	
30	Air Conditioner (230 V)	Coleman	Polar Cub 9.2K BTU

31	Space Heater (230 V)	McMaster	19095K742
32	DC Power Supply +15V	Acopian	15EB100
33	DC Power Supply +5V	Acopian	5EB150
34	Power Supply Mounting Bracket	Acopian	EB4A
35	UPS (120 V) 1500 W	Newegg	SM1500RM2U
35.1	UPS (230 V) 1000 W	B&H	APCSUA1000RM
36	PDU (120 V)	B&H	AP7900
37	Power Strip (120 V)	APC	NET9RMBLK
37.1	Power Strip (230 V)	APC	AP9565
38	Network Hub	Newegg	GS105
38.1	Circuit breaker bar	Gear Box	SLP-237
38.2	IP-KVM	Opengear	IP-KVM-1001-US
39	ProtectNet Surge Suppressor	Newegg	PNET
40	Enclosure	Kleeberg	
40.1	racks	Starcase	
41	GPS	Raven	Phoenix
42	Inclinometer	Rieker	H4A1-30
43	Solid State Relay (120 V)	Omron	G3NA-210B-AC100-120

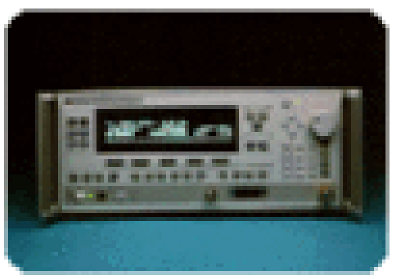

Figure 3. Test equipment used for the measurements (Agilent E4440A spectrum analyzer and an HP 83630L synthesizer.

1) Transmitted power: (68 dBm min.):
   Measurements were made with the E4440A spectrum analyzer and a calibrated assembly of a 21 dB waveguide coupler, 30 dB waveguide attenuator, an SMA-to-WR90 waveguide adapter (0.2 dB loss), a 10 dB coaxial attenuator and a coaxial cable (1.83 dB attenuation @ 9.41 GHz). Total attenuation in the power sampling waveguide assembly is approximately 61.85 dB. Unused transmit port was terminated with high-power waveguide loads. The magnetron was transmitting 1 microsecond pulses while the Spectrum analyzer was configured to the maximum, 2 MHz resolution bandwidth and measuring the peak power of the transmitted spectrum.

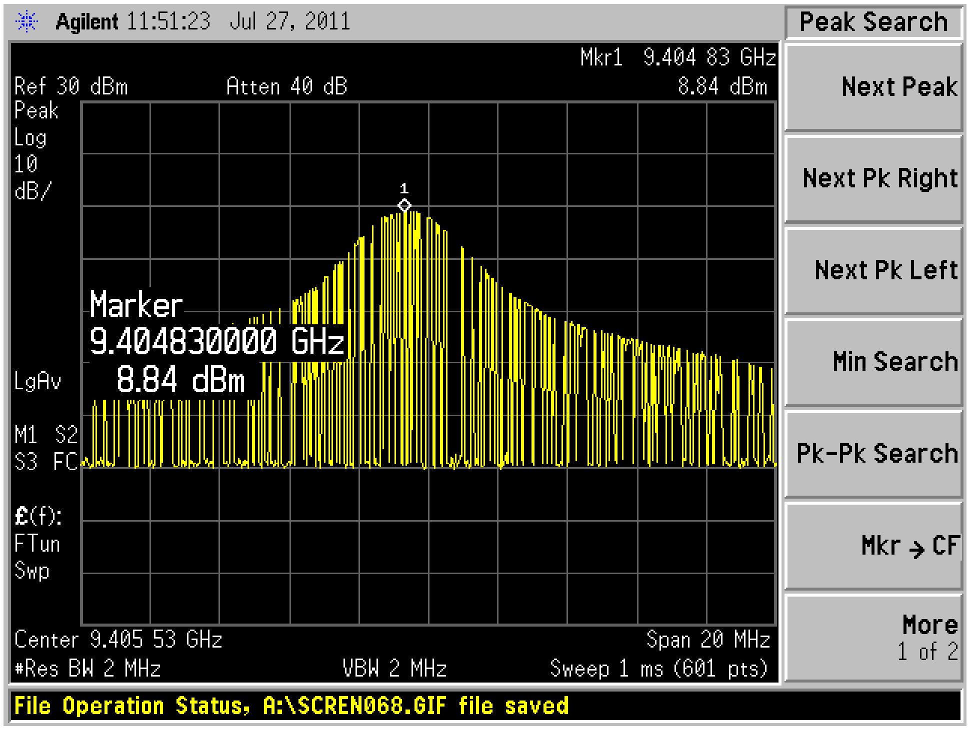

Figure 4. Ch1 (V-pol) transmitted signal spectrum (1 us pulse, 2 MHz Res. BW.).

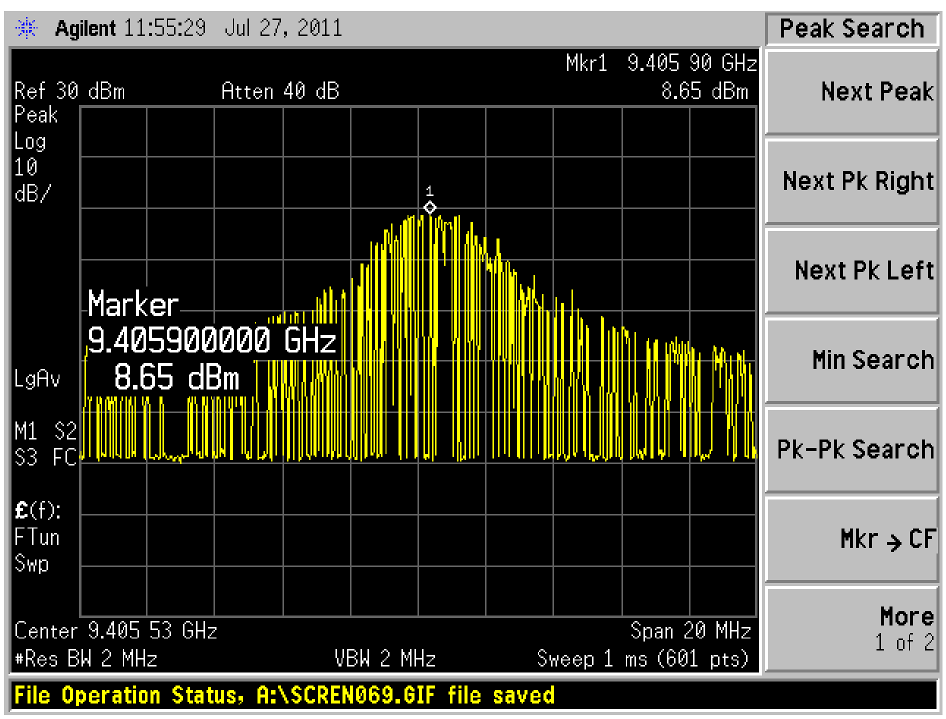

Figure 5. Ch2 (H-pol) transmitted signal spectrum (1 us pulse, 2 MHz Res. BW.).

i. At RF box V-port: 70.7 dBm (11.7 kW)

ii. At RF box H- port: 70.5 dBm (11.2 kW)

The transmitter pulse is also sampled by the V port of the digital receiver during transmission.

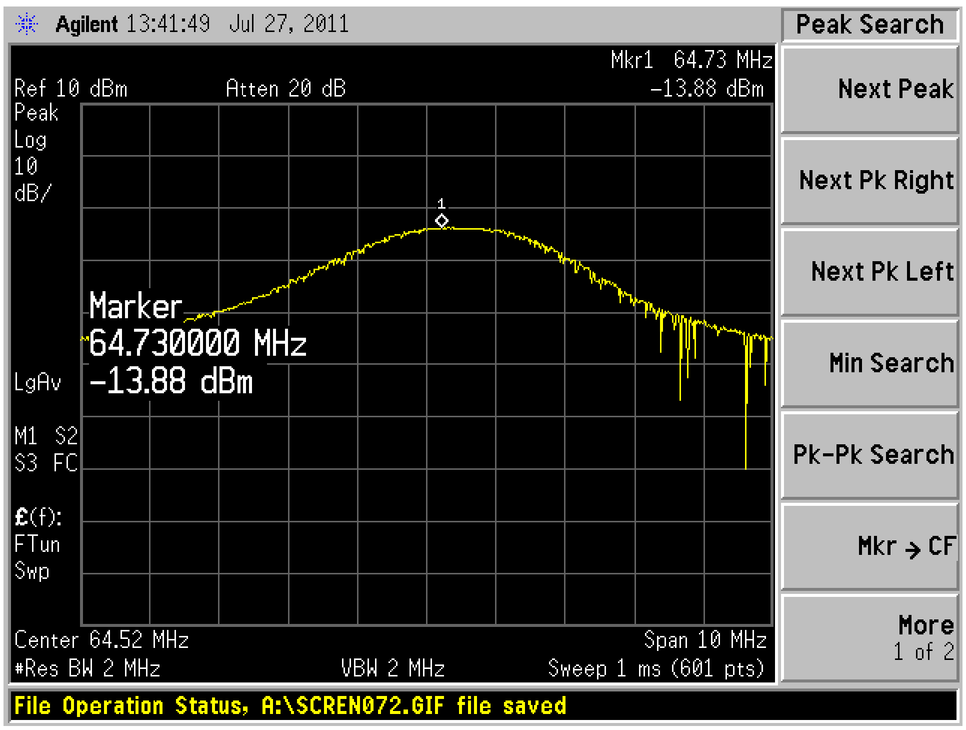

Figure 6. Internal calibration channel sample of the transmitted pulse spectrum. The -13.9 dBm peak pulse power at the V-port digital receiver input connector corresponds to full power transmission and a frequency locked receiver.

2) Receiver Gain:

i. From the RF enclosure V waveguide port to Ch1 IF digital receiver input: 31.0 dB

ii. From the RF box H waveguide port to Ch2 IF digital receiver input: 31.6 dB

3) Receiver Noise Figure:

   i. From the RF enclosure V waveguide port to Ch1 IF digital receiver input: 3.3 dB

   ii. From the RF box H waveguide port to Ch2 IF digital receiver input: 3.2 dB

Measured with HP83712A synthesizer, calibrated coaxial cable and SMA-to-WR90 adapter and an Agilent E4440A spectrum analyzer. A -70 dBm, 9.41 GHz signal is injected into the waveguide port (-68.2 dBm configured on the HP83712A minus 1.8 dB cable loss). The internal pre-amp of the spectrum analyzer should be turned on (under "Amplitude, 2nd screen) and configured for 1 MHz resolution bandwidth. Using a Delta Marker, the difference between the signal peak at 60 MHz and the noise floor about 3 MHz above or below the signal peak can be used to estimate the noise figure.

$$NF = \frac{SNR_{in}}{SNR_{out}} = \frac{10^{-7} / kTB}{SNR_{out}} = \frac{10^{-7} / 1.38\times10^{-20}\times296\times10^{6}}{SNR_{out}} = 43.9 - SNR_{out}\,(dB)$$

Where kTB is the thermal noise power at the receiver input (when matched).
k = Boltzman's constant = 1.38E-20 mW K^{-1} Hz^{-1}
T = Receiver temperature in Kelvins = ~296 K
B = Receiver bandwidth = 1 MHz (here set by the resolution bandwidth of the spectrum, analyzer)

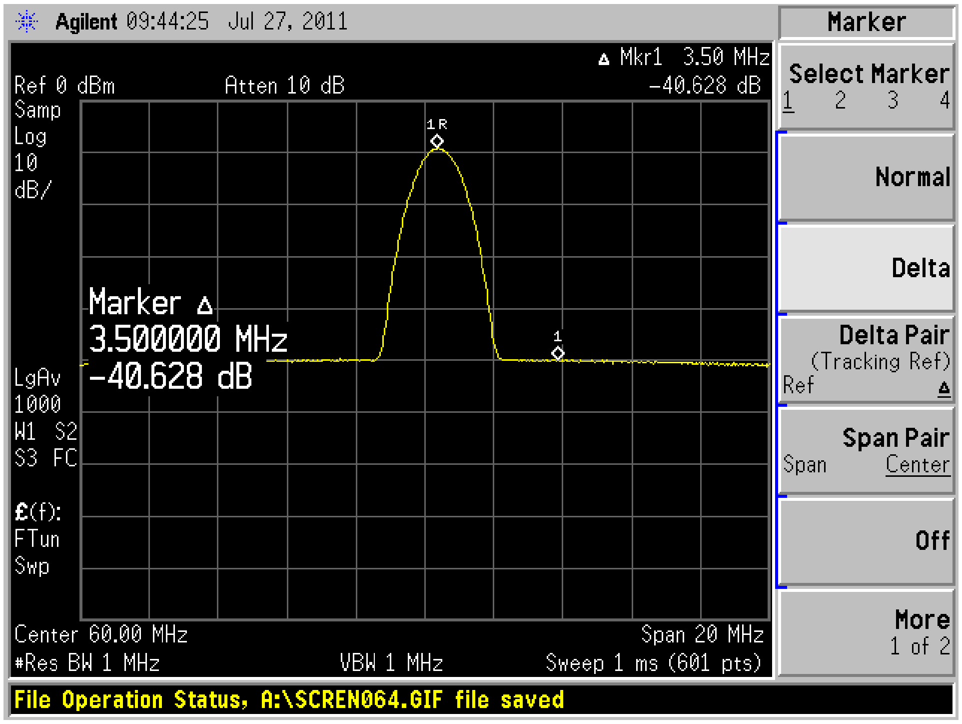

Figure 7. RF box, V-port output SNR (40.63 dB).

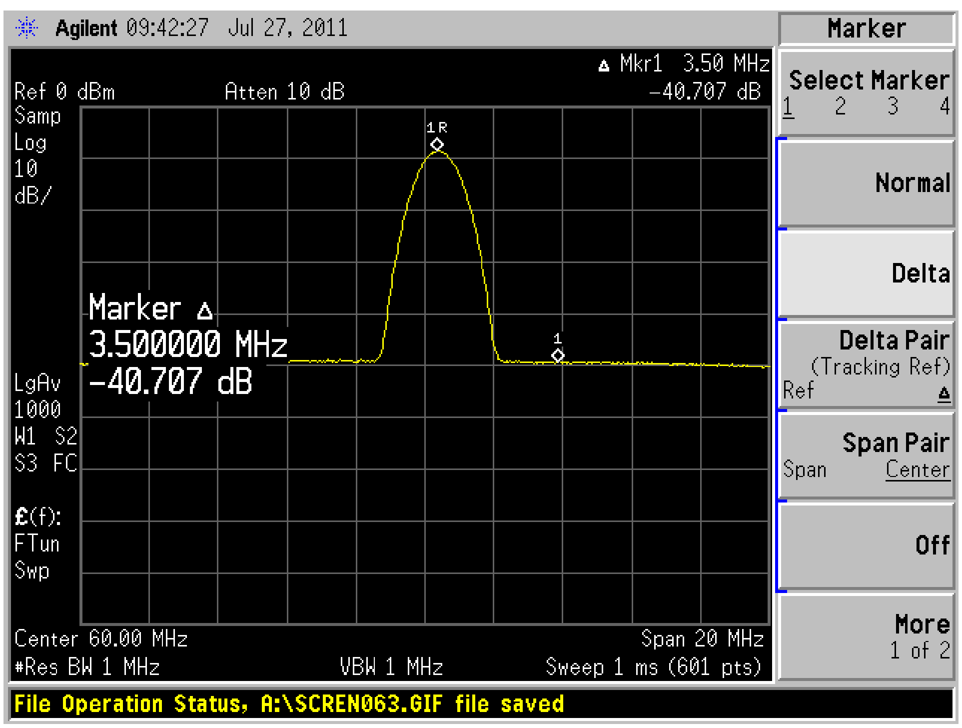

Figure 8. RF box H-port output SNR (40.7 dB)

4) Radar Pod to Antenna Insertion Loss
   i. V-port (Ch 1): 0.92 dB

   ii. H-port (Ch 2): 0.79 dB

This insertion loss was measured from the Radar Pod waveguide ports to the antenna feed-end of the antenna flexible waveguide - combined insertion loss of the flex waveguide between the pod and the pedestal, the pedestal waveguides including the (azimuth) rotary joint and antenna flex waveguide between the pedestal elevation head waveguide ports and the antenna feed.

5) Receiver Isolation

   i. V IF port (when signal injected into H RF port) 46 dB

   ii. H IF port (when signal injected into V RF port 48 dB

6) Calibrated Transmit Pulse Sample in Ch1 (see the "TX Pulse Sample" line in Figure 2). This is a third, calibration receiver channel, used during transmission to monitor the transmitted pulse and the digital receiver frequency tracking.
   i. 1 dB compression of Ch1 Tx sampling receiver: +6 dB

   ii. Data system Ch1 TX pulse sample at full power: -13.9 dBm

   Measured with the spectrum analyzer at the IF port of the RF box. An HP83712A synthesizer was used to feed an X-band signal into the receiver for the 1 dB compression measurement.

7) Transmit Frequency: 9.408 GHz +- 6 MHz

8) Transmit Pulse Shape:

The X-band radar transmit pulse shape and length was measured by observing the RF pulse out of the Channel #1 IF port (with the TX pulse sample switch) using an Agilent DSO7104B digital oscilloscope and a Mini-Circuits SIF-60+ bandpass filter.

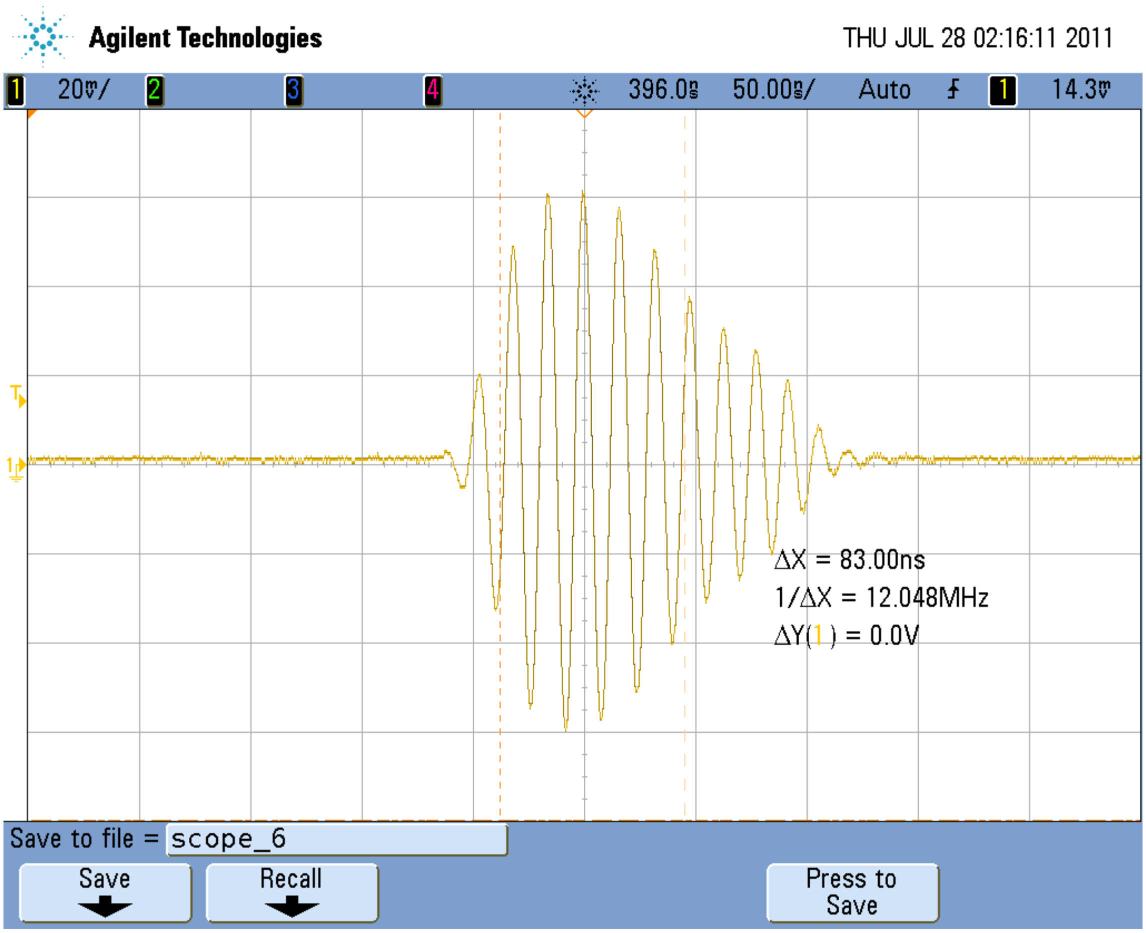

Figure 9. The 15 m range resolution (100 ns) TX Pulse.

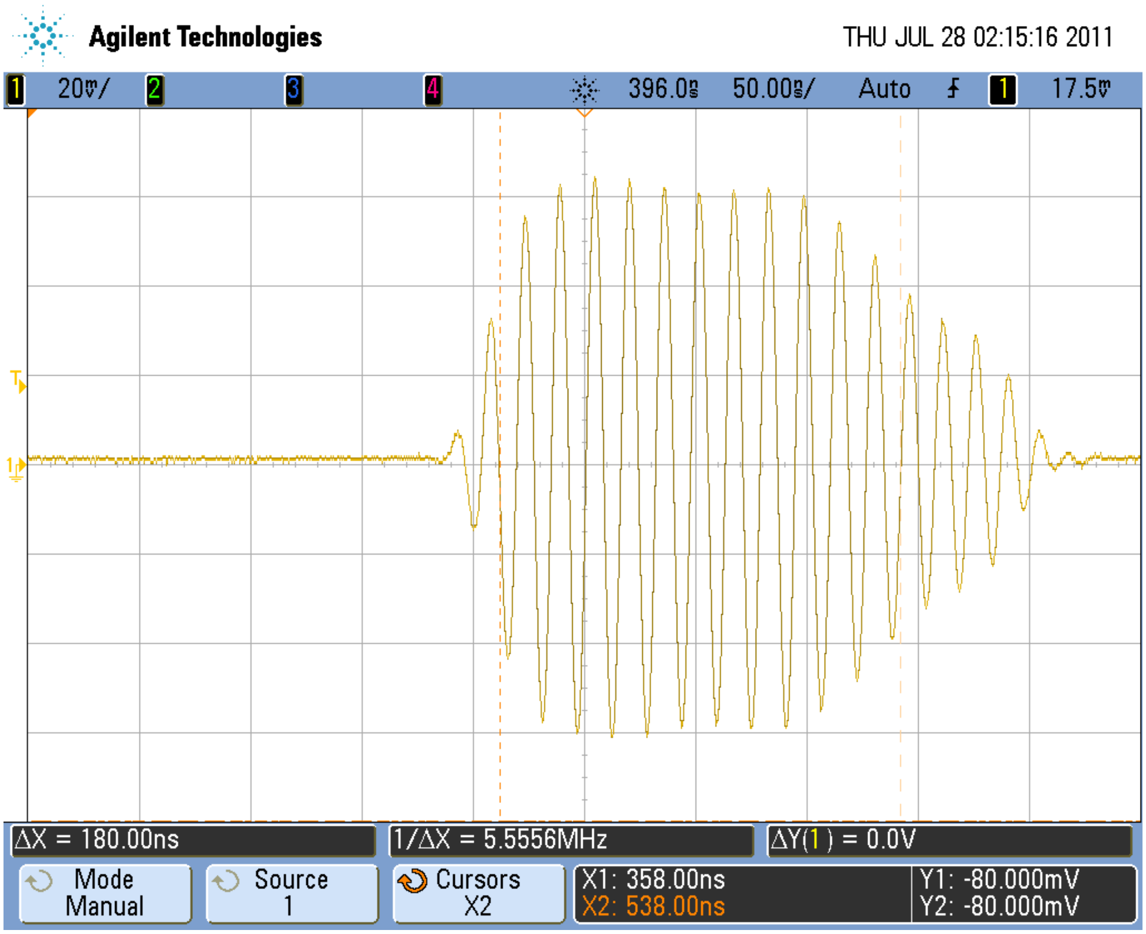

Figure 10. The 30 m range resolution (200 ns) TX Pulse.

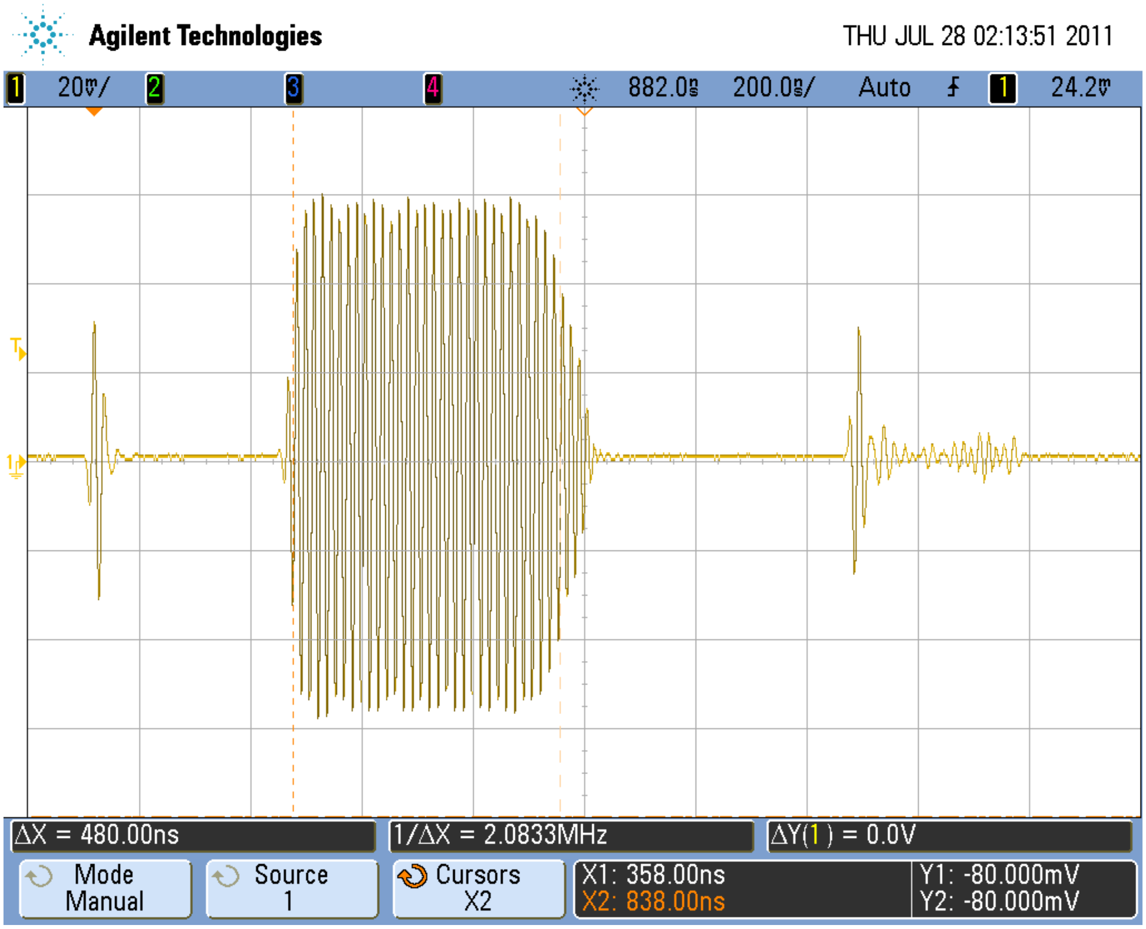

Figure 11. The 75 m range resolution (500 ns) TX Pulse.

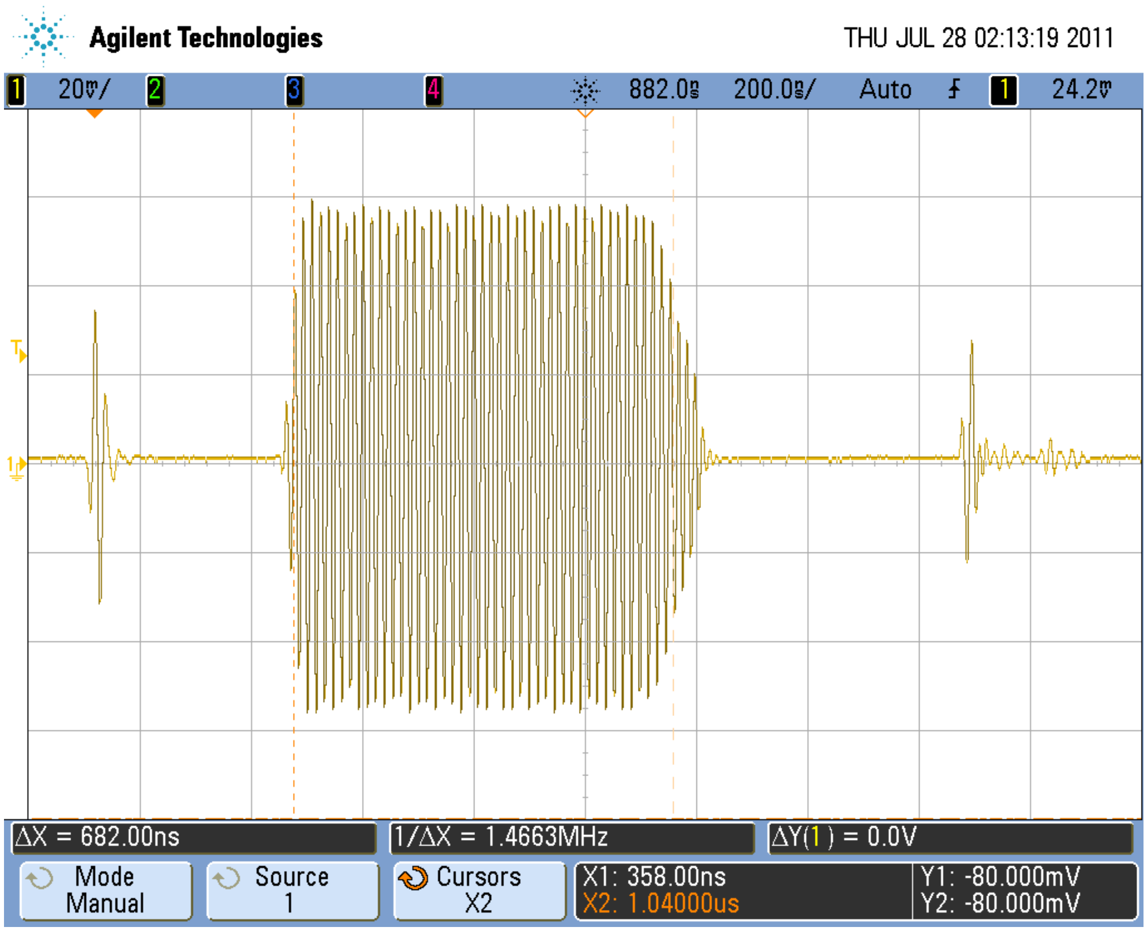

Figure 12. The 105 m range resolution (700 ns) TX Pulse.

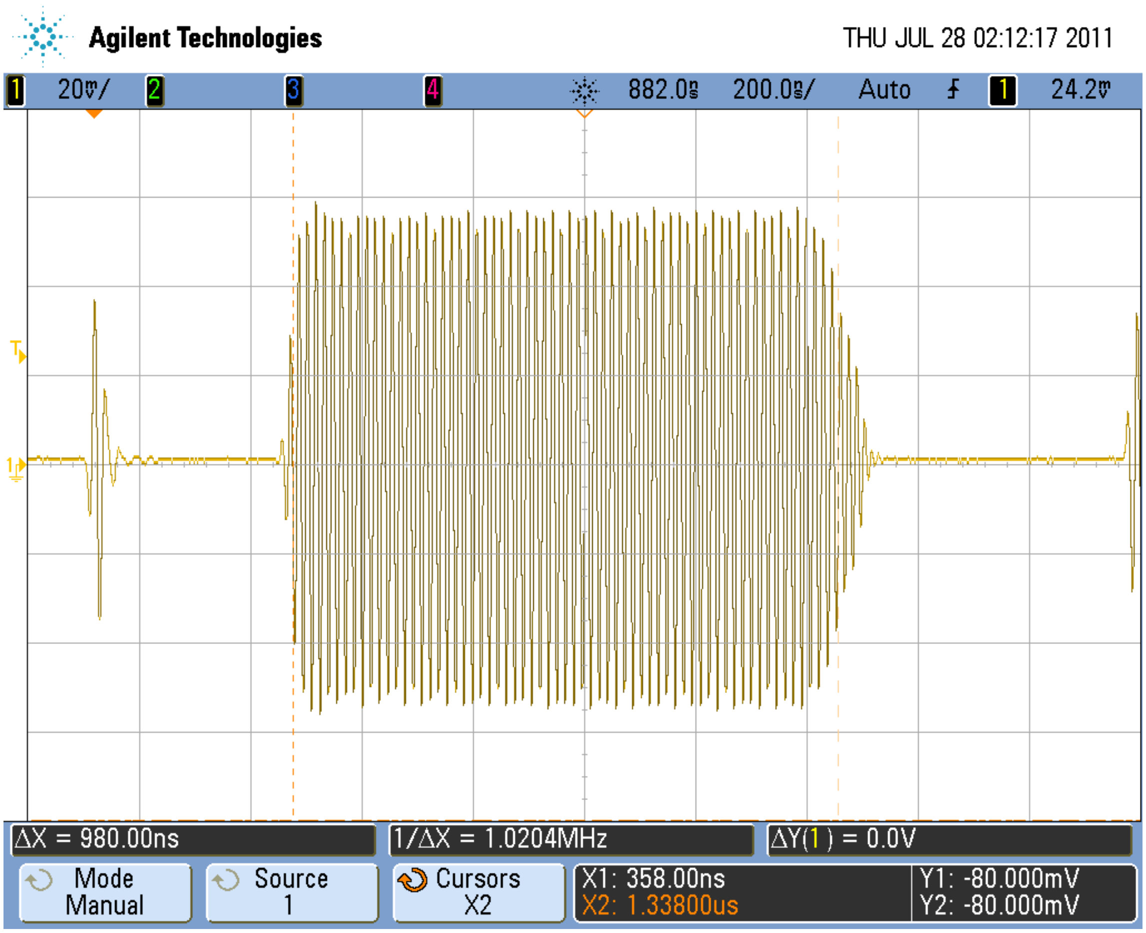

Figure 13. The 150 m range resolution (1000 ns) TX Pulse.

B. Pedestal

1) Azimuth maximum speed: tested to 20 deg/sec.
2) Elevation maximum speed: tested to 20 deg/sec
3) Elevation range: -1 to +181 deg
4) Elevation and Azimuth encoder (data) resolution: 0.0055 deg.
5) Elevation pointing precision (repeatability): <0.1 deg.
6) Azimuth pointing precision (repeatability): <0.1 deg.
7) Scan patterns:

    i. Continuous azimuth, fixed elevation (Vel_az, El)

ii. Azimuth sector, fixed elevation (Vel_az, Az1, Az2, El)
iii. Elevation sector, fixed azimuth (Vel_el, El1, El2, Az)
iv. Raster (Vel_az, Az1, Az2, Vel_el, El1, El2)
v. Stepped Volume (Vel_az, El1, Delta_El, N_El)
vi. Point (Az, El)

C. Data System

1) Data Acquisition and Processing Modes:

i. Pulse Pair (Zh, Zv, Single-lag Pulse Pair Velocity, Differential Phase)
ii. Dual Pulse Pair (Zh, Zv, Dual-lag Pulse Pair Velocity, Differential Phase)
iii. FFT (Sh, Sv, Svh)
iv. FFT2 (Sh1, Sh2, Sv1, Sv2, Svh1, Svh2)
v. FFT2I (Sh1, Sh2, Sv1, Sv2, Svh1, Svh2)

2) Processing Capacity (parallel processing, ~50% loading of the 4 processors):

i. PP: 3000 range gates @ 1 kHz average PRF
ii. DPP: 3000 rg @ 1 kHz PRF
iii. FFT 2000 rg @ 1 kHz PRF (64 points tested)
iv. FFT2 1000 rg @ 2 kHz PRF (64 points)
v. FFT2 1500 rf @ 1 kHz PRF (64 points) – memory limited
vi. FFT2I 1000 rg @ 2 kHz PRF (64 points)
vii. FFT2I 1500 rg @ 1 kHz PRF (64 points) – memory limited

D. Signal Measurements

The Xpol radar signals at key locations, shown in Figure 14, were measured with an Agilent E4440A spectrum analyzer The corresponding signal measurements are shown in Figure 15 and Figure 16.

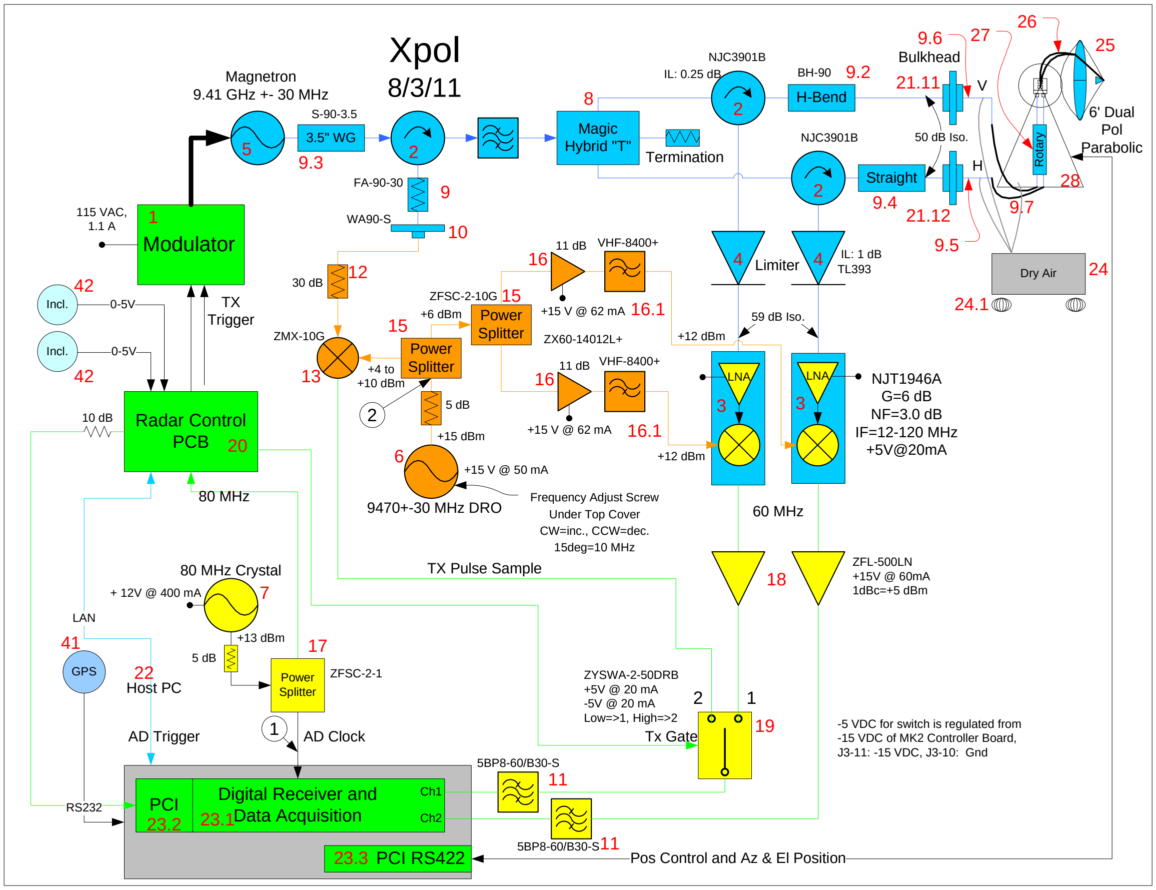

Figure 14. The Xpol component level block diagram. Critical signal locations are indicated with numbered callout circles.

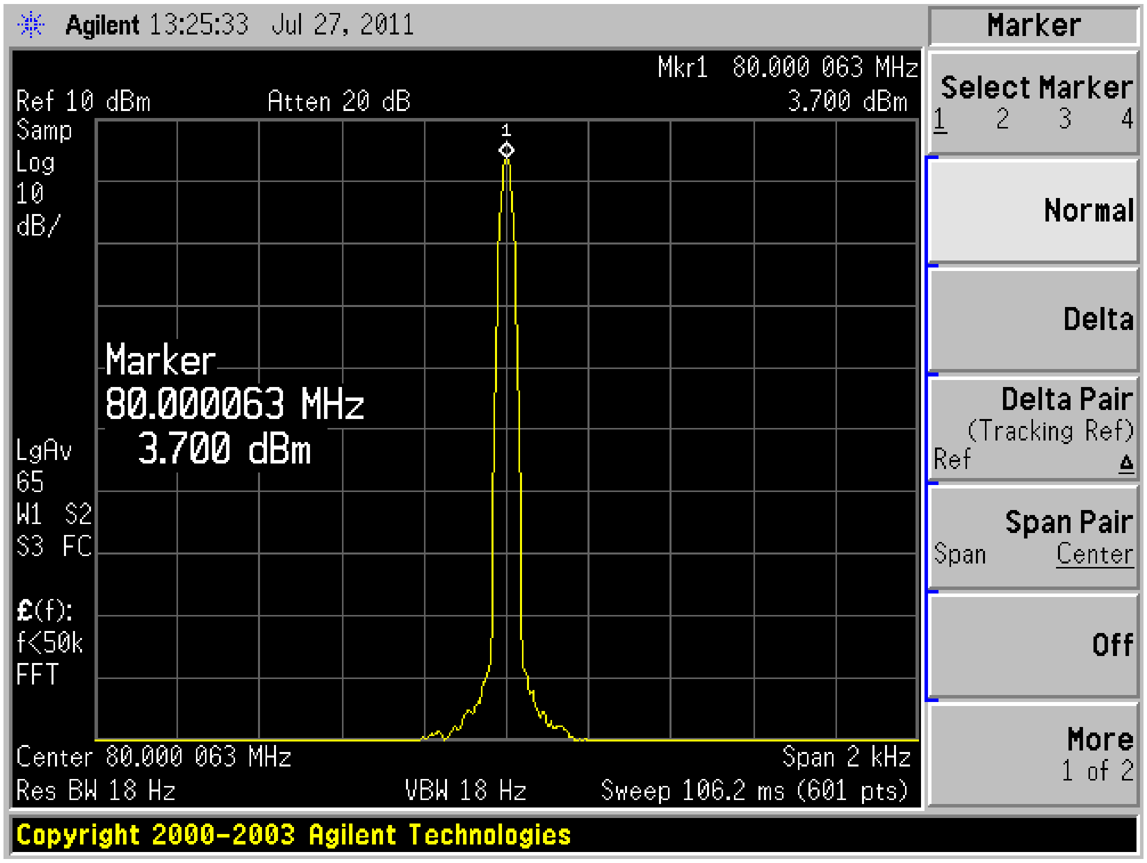

Figure 15. Test point #1: 80 MHz crystal AD clock.

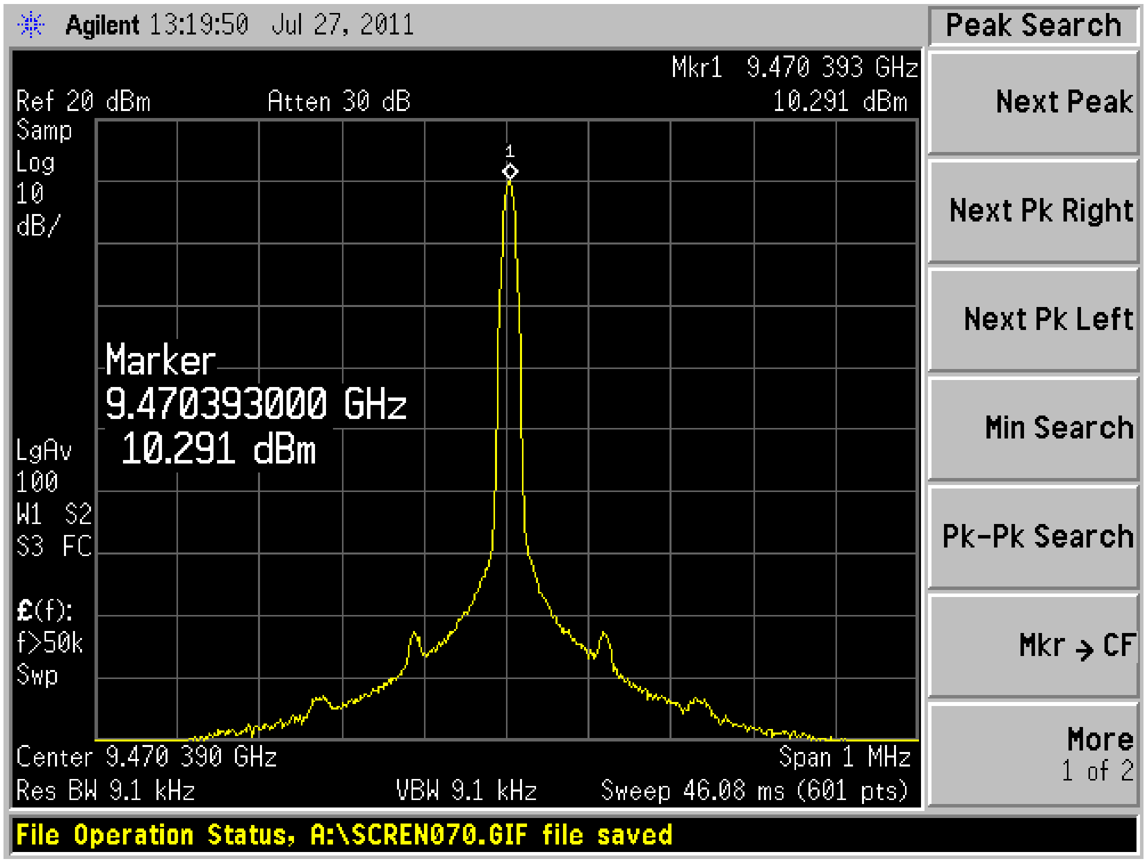

Figure 16. Test point #2: 9.47 GHz DRO signal after the 5 dB attenuator, into the first splitter (not accounted for cable loss, so actual signal power is about 12 dBm).

E. Photographs

Figure 17. Xpol system, shown with the pedestal break release cables attached and activated to test the antenna balance with the counter weights.

Figure 18. Flexible waveguides connected to the pedestal and antenna ports.

Figure 19. The Xpol RF pod transfer from the assembly table to the shipping pallet using a hoist and straps.