Memo

TO:	RFI group
FROM:	Phil Perillat
DATE:	27 april 1997
RE:	Lband radars
update:	5 may 1997, 25jan99

The L-band radars were measured using the gregorian receiver system. The radars measured were done in April and May of 1997. The setup and analysis method are followed by tables containing the frequency, ippcycle, ipps, number of pulses, pulse lengths, bandwidths, and rotation rates. Notes on each radar accompany the table. It was not possible to record all values accurately for all radars (weak signals, multiple radars at the same frequency, too much multipath scattering, etc.). The radars listed below and their values reflect what was transmitted during the observing time. There may be more radars, and the recorded values for some of these radars may change with time (frequency and ipp agility). The last page is an update using the scope to measure new radars.

Terminology

PRF or Pulse Repetition Frequency is the frequency that the radar transmits pulses. A single transmission may contain one or more pulses.

IPP is the InterPulse Period. This is 1/PRF.

IPPCYCLE is the number of ipps of differing lengths that are transmitted before the sequence repeats.

Setups

Two different setups were used. Complex I Q sampling and post detection sampling. In both cases the i/o limitation rate was 400 Kilobytes per second. This is two samples at 10 microsecond sampling or 4 samples at 20 microsecond sampling.

1. Mix RF to 260mhz then 30Mhz
   Filter with 125Khz butterworth filter
   Down convert to baseband and complex sample at 10 microsecond sampling on one frequency
   Record 100 seconds of data
2. Mix RF to 260
   Down convert to 30Mhz using up to 4 separate LO's giving 4 bands.
   Filter with a 1 Mhz butterworth or gaussian filter (we only had 2 of each).
   Detect the signals with a time constant of 20 or 50 microseconds (depending if there were 2 or 4 separate frequencies).
   Sample the up to 4 signals simultaneously at 10 or 20 microseconds for 100 seconds.

Setup 1. was used to measure an individual radar frequency. Setup 2 was used to measure radars that used more than one frequency.

Analysis

The sample rate was 10 or 20 microseconds continuously for 100 seconds. Assuming a one sample (10 microsecond) measurement error, then the measurement error in the ippcycle would be 10 microseconds / (ippcycles in 100 seconds). For a 10 millisecond ippcycle the measurement error in 1 ippcycle would be 1 nanosecond. The actual error (after folding with the computed period) was larger probably do to variations in the transmitter. The ippcycles are accurate to at least .1 microseconds.

100 milliseconds of data was plotted and the ipps extracted (using a search for peaks above a threshold). These ipps were plotted to get a first guess at the ippcycle. This value was used to compute the position of the ippcycle 10 seconds later. The actual position of the cycle was then used to recompute the ippcycle. This was done at 10 second steps until the last value was used to predict the position at 100 seconds.

The data was then folded at the ippcycle values computed above.

For radar rotation rates of 12 seconds, there were 8 times that the radar pointed at the observatory. This would give up to 8 large peaks in the recorded signal. The ippcycle was varied by small amounts (.001 to .1 microseconds) to see if the spread of the peaks could be narrowed.

The folded data was then smoothed and gaussians were fit to compute the individual ipp values. The ipps should be accurate to .1 microseconds except when the folded data was noisy.

The bandwidths were difficult to measure because of the sweeping nature of the signal. The best technique was to leave the spectrum analyzer on peak hold for a long time and watch the average bandpass buildup.

The pulse length and number of pulses were also difficult to measure because of the multipath scattering. A two pulse transmission could look like a single pulse because of the smearing.

Aerostat radar

The aerostat radar is an L-88A radar with a published prf of 305 hz and a bandwidth of 1.667 Mhz. The measured prf is closer to 304 hz.

The aerostat radar has been seen running in a 4 frequency mode (1261, 1256, 1244, 1241) and a 2 frequency mode (1256, 1241) and (1261.25, 1246.2) The dual frequency mode might also use other combinations.

The aerostat radar blanks its beam (see fig 4.0) when it points at Arecibo. This blanking lasts for 42 degrees of azimuth or 1.356 seconds.

A 1234 Mhz radar with a 10 microsecond pulse was seen to blank with the aerostat.

How often are the radars on?

The 1350/1330 Mhz airport radar is always on.

The aerostat radar seems to be on with one of its modes most of the time.

The 1306.9 Mhz radar seems to be around a lot.

The 1294.6 radar comes and go.

The 1110/1106 Mhz radars seem to always be there.

The radars with 15 ipp cycle and 3.86 second rotation rate might be frequency agile radars since the same type of radar appears at many different frequencies.

This topic needs to be investigated using the interference monitoring database.

Radar table 1

	1350 1330 faa	1306.9	1300.5 1285.2	1294.6	1282.4	1256.5 1241.75 aerostat	1261.25 1246.2 aerostat
ippcycle	14104.83	2781.68	30098.49	2736.85 2736.492	2778.379	23028.6	
num ipps	5	1	15	1	1	7	
num pulses	1 1	1	2 1	1	1	1	1
pulse len	5 5	5	1 1	5		160 160	61 160
bw (mhz)	1 1	.2	1 1	.2	1-2	1.667 1.667	1.667
rotation	12	12	3.87	12	3.86	11.59	11.59
date	23apr97	23apr97	30apr97	23apr97 2may97	30apr97	23apr97	3may97
ipps	2633.08 2821.00 2745.96 2594.84 3309.96	2781.68	2224.11 1932.26 2207.82 1900.40 2191.88 1880.02 2176.00 1864.21 2141.81 1847.85 2077.76 1832.15 2029.95 1816.10 1976.18	2736.85	2378.379	2808.48 2904.18 3289.73 3675.57 3770.95 3504.17 3075.52	2808.62 2903.97 3289.79 3675.59 3770.97 3504.04 3075.61
notes	*1	*2	*3 *13	*4	*5 *13	*6	*7

Radar table 2

	1261.25 1256.5 1244.6 1241.75 aerostat	1246.5	1231.5	1228.5	1110	1106		
ippcycle		14999.81	15050.18	15050.33				
num ipps	7	15	15	15				
num pulses	1 1 1 1	1	1	1	2	2		
pulse len	160 160 160 160	30	1?	1	5	5		
bw (mhz)	1.667 1.667 1.667 1.667	1 - 2 ?	1-2	1-2	.2	.2		
rotation	11.59	3.86	3.86	7.76				
date	23apr97	28apr97	1may97	1may97	3may97	3may97		
ipps		1000.14 1005.54 991.47 1010.97 984.92 1016.71 981.68 1019.06 985.84 1017.61 985.76 1015.00 990.36 1002.44 992.31	1043.00 974.20 1028.74 969.11 1024.83 985.08 992.58 929.32 1000.32 1089.69 967.57 1075.22 967.80 1033.05 969.66	1087.66 931.44 1071.90 923.28 1039.18 916.27 1014.18 909.41 988.80 1110.80 966.42 1104.43 949.24 1096.33 940.99				
notes	*8	*9 *13	*10 *13	*11 *13	*12	*12		

Radar Table 1 notes:

1. 1350/1330 Mhz

   FAA airport radar. 1 microsecond pulse with about 5 microseconds of multipath scattering. 1350 pulse starts at t=0. 1330 pulse starts at t=9 microseconds.

- Figure 1a shows 100 seconds of 1350 Mhz data folded at 14104.83226 microseconds.
- Figure 1b is the pulse shape for the first ipp for 1350 Mhz.

2. 1306.9 Mhz radar.

- Figure 2.a shows 100 seconds of data at 2781.678733 microseconds. There are a lot of spikes in the figure. A 1 microsecond error would have smeared the pulse over 35 milliseconds or 15 periods. On the other hand with a 12 second rotation there are only 8 times when the beam points at us. This radar probably should be looked at again.

3. 1300.5/1285.2 Mhz radar

   Looks like a double pulse on 1300 and a single pulse on 1285. 1300P1 starts at t=0. 1300P2 starts at t=20 microseconds. 1285P1 starts at t=30 microseconds.

- Figure 6.a shows 100 seconds of data at 1300.5 Mhz folded with a period of 30098.49 microseconds.
- Figure 6.b shows the first pulse of the 1300.5 (solid line) and the 1285 (dashed line). The 1285 follows the 1300 Mhz pulse. This data had a 20 microsecond time constant applied to it.

4. 1294.6 Mhz radar.

   The radar was measured on 2 may 1997 and 28 april 1997. The ipp differed by .4 microseconds. With over 36000 periods in 100 seconds, this difference would smear the folded data by 14.4 milliseconds or 7 complete periods (if I had used an incorrect period). The folded data for the two days was not smeared, so the radar must have drifted its ipp by .4 microseconds.

- Figure 3.a shows 100 seconds of data folded at 2736.8522 microseconds. There is a spread of 15% or 410 microseconds. This could be an error of 410/36000 = 11 nanoseconds in the period.
- Figure 3.b shows the same data folded at 3 different periods:2736.847, 2736.852, and 2736.862. These are steps of 5 and 10 nanoseconds in the period. The narrowest set was that of 2736.852. The 8 peaks are the 8 rotations of the radar in 100 seconds. So none of the periods are perfect.
- Figure 3.c shows data taken on 2may97 for 100 seconds and folded at 2736.492 microseconds. There are only 4 peaks. So two rotations of the radar fell exactly on top of another rotation. This implies that the radar ipp is drifting during the 100 seconds. The drift is 310 microseconds over 100 seconds. This is 9 nanoseconds in the period or 1 part in 3e5 over 100 seconds. The period difference of .4 microseconds between the

23april and 2may data would smear the data by .4microseconds*36000 or 14 milliseconds. This is 7 full periods.

5. 1282.4 Mhz radar.

- Figure 10.a shows 100 seconds of data folded at 2778.379 microseconds.

6. 1256.5/1241.75 Aerostat dual frequency mode

   The 1256 pulse starts at t=0 and the 1241 pulse follows at t=160 microseconds.

- Figure 4.0 shows a 12 second rotation with the 1.356 second blanking done by the aerostat radar itself.
- Figure 4.a shows 100 seconds of data folded at 23028.6 microseconds. 1256 Mhz is the trace with the lower baseline and 1241 Mhz is the trace with the higher baseline.
- Figure 4.b is the first ipp of the ippcycle. The 1256 Mhz pulse is followed by the 1241 Mhz pulse.

7. 1261.25 / 1246.2 Mhz aerostat radar

   The 1261 pulse starts at t=0 and the 1246 pulse starts 160 microseconds later. The time constant on the data was 20 microseconds. The 1261 pulse was only 60 microseconds wide instead of the normal 160 microsecond width for the aerostat.

- Figure 9.a shows the 1261 and 1246 signals folded for 100 seconds at 23028.6 microseconds.
- Figure 9.b shows the first pulse of the 7 pulse period after folding for 100 seconds. The 1261 pulse precedes the 1246 pulse. The 1261 pulse is only 60 microseconds wide instead of the normal 160 microseconds. There was a 1 Mhz butterworth filter on the signal so I doubt if the difference could be that they were jumping between 2 frequencies within the 1.667 Mhz bandwidth.

8. 1261.25/1256.5/1244.6/1241.75 Aerostat radar 4 frequency mode.
   I haven’t taken simultaneous data on this mode yet.

9. 1246.5 Mhz radar

   The interference monitoring data shows frequencies 1214 and 1229 Mhz appearing and going away with 1246.5 Mhz so this may be a multifrequency radar (although the other frequencies weren’t visible when I took the data).

- Figure 5.a shows the 15 ipp cycle folded for 100 seconds with the period 14999.81 microseconds.
- Figure 5.b shows the first 4 ipps of the 15 ipp cycle after averaging for 100 seconds.

Radar table 2 notes

10. 1231.5 Mhz radar.

    1231.5 and 1228.5 have rotation rates that are a multiple of one another, but they have different ippcycles and ipps. The rotation peaks were not coincident with one another.

- Figure 7.a shows the 15 ippcycle folded for 100 seconds with the period 15050.184 microseconds.
- Figure 7.b shows the first pulse after folding.

11. 1228.5 Mhz

- Figure 8.a shows 100 seconds of data folded at 15050.330 microseconds.

12. 1110/1106 Mhz radar

    1110 and 1106 both have double pulses separated by 12 microseconds. The ipp cycle and ipp lengths change rapidly with time. 1106 appears to have a 40 millisecond ipp and then changing to 47 milliseconds. There are many subipps that come in and out during this time. I didn’t have much luck folding this data.

13. radars with 4 second rotation rates are probably atc (air traffic control) radars. Either san juan or an aircraft carrier.

Other signals

- 1090.7 Mhz

  Pulse length 60 to 70 microseconds. It doesn't look like a radar. Probably a communications channel.

Other radars measured via scope/spectrum analyzer

freq	**1271**	**1237.1**	**1297.4**				
ippcycle	2782	1050	1840 to 2240				
num ipps	1 ?	1?	multi				
num pulses	1?	1?	1				
pulse len	<5	a few usecs	about 60				
bw (mhz)	<2	<1.6	<2				
rotation	12	3.88	3.88				
date	22jan99	22jan99	25jan99				
ipps	2782	1050	2240 1920 2160 1920 2160 1840 2160 1840 *scope				
notes	*1	1* 2*	2*				

1. bw is max distortion bandpass. actual bw probably much less. ipps not measured accurately.
2. measured using scope. E. hernandez at remy said that 4 second rotation radars are ATC (air traffic control) radars used for close approach. It is either the san juan radar or an aircraft carrier.