EXPERIMENTAL RETURN STRENGTHS FROM OPTUS-B AND GPS

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EXPERIMENT DESCRIPTION

PURPOSE: To take a first step in characterizing retroreflector arrays in their actual space environments.

AIM: To compare return SLR signal strengths from GPS35/36 and OPTUS B1/B3, and hence find ratio of their lidar cross-sections.

METHOD: Range in successive "bursts" to a GPS and an Optus B target when they are in close proximity in the sky (< 5^{o}, say). In each burst:

(a) Maximize return rate by fine pointing adjustments;

(b) Then adjust ND filter in Receive Path until returns are just extinguished.

THEORY

BRIGHTNESS: Return signal strength when pointing is optimized.

B Brightness at extinguishment, i.e. detection threshold (assumed constant)

V Vacuum Brightness, corrected for ND filter (N), laser transmitted power (P), atmosph.Transmission (T, 1-way)

$V = k.B / PNT^2$ (k is a proportionality constant)

CROSS-SECTION: $[\sigma = n.4\pi (A / \lambda)^2]$

C Relative cross-section, <u>observed</u>, assuming normal incidence angle etc.

R Distance from telescope to satellite

$C = VR^4 = k.B.R^4 / P.N.T^2$

CORRECTION FORMULAE

NEUTRAL DENSITY FILTER

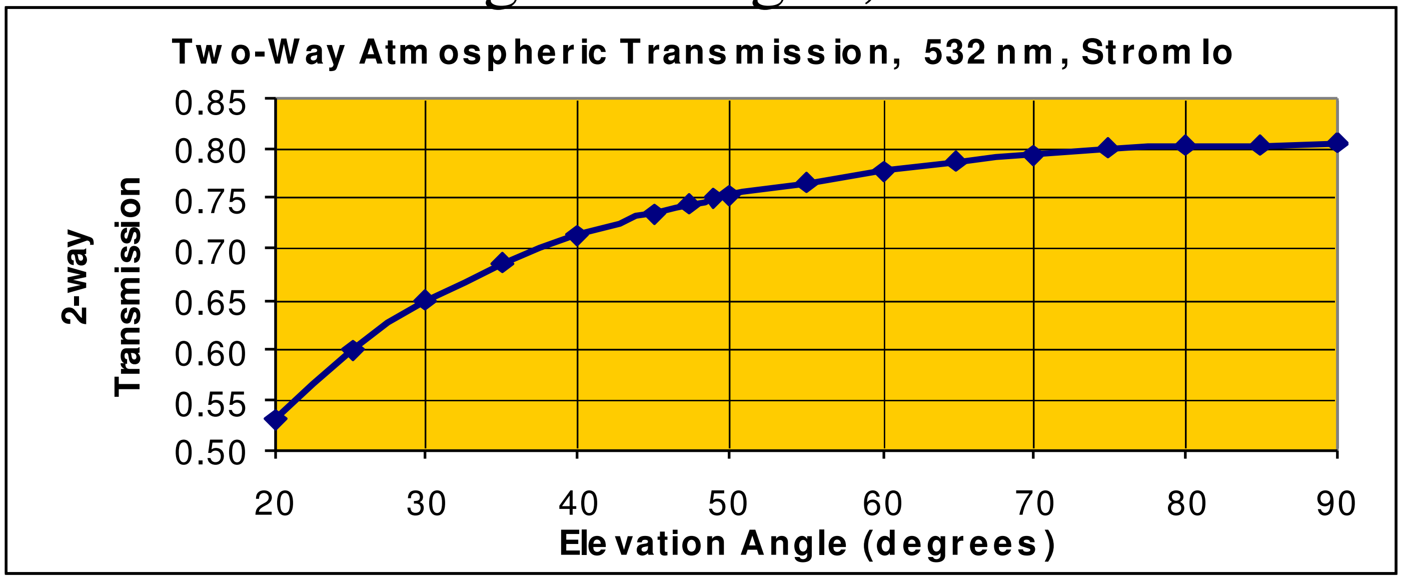
$N = 10^{-ND}$ where *ND* is ND filter wheel setting

ATMOSPHERIC TRANSMISSION

(*from Degnan, 1993*)

$T = \exp\{ -0.21072 \exp(-h/1.2) / \sin E \}$

Where *h* km is station geoid height , *E* is Elevation Angle



SATELLITE CHARACTERISTICS

OPTUS B1 and B3

Geostationary Orbits, $a = 42165$ km, $i \approx 0^o$, $e \approx 0$
B1: Longitude 160°E, Az, El from Stromlo: 18.6°, 47.4°
B3: 156°E 5.0°, 48.9°

Array: 14 tri-roundular solid Herseus fused silica cubes, inscribed diameter 38 mm, mounted in 20 cm x 18 cm tray, Vespel O-rings. Indium Tin Oxide coatings on all faces.

Theoretical Array Cross-Section: 46×10^6 m^2 @ 532 nm (*Arnold, 2006*)

GPS 35 and 36

Array: 32 solid fused silica cubes 25 mm diameter, Al coated on reflecting surfaces

Theoretical Array Cross-Section: 20×10^6 m^2 @ 532 nm *(Arnold, 2006)*

OBSERVATIONS, May 2006

Date (May'06)	Target	El (deg)	Power (W)	ND	V	Rej
10	GPS36	75.9	9	2.8	78.1	
	B1	47.4	9	2.2	21.1	
	GPS36	39.5	9	0.5	0.5	*
	B3	48.9	9	4.0	1480.7	*
13	B3	48.9	2	2.0	66.6	
	GPS 36	40.9	2	3.0	695.8	*
	B3	48.9	2	2.0	66.6	
15	B3	48.9	12	3.0	111.1	
	GPS36	85.0	2	1.9	49.4	
	B3	48.9	2	0.9	5.3	
	GPS36	63.6	2	2.3	127.0	
	GPS36	61.7	2	2.9	507.8	
	B3	48.9	2	0.6	2.7	
	GPS36	55.6	2	2.4	163.3	
	B3	48.9	2	0.8	4.2	
	GPS36	46.2	2	2.1	85.0	
	B3	48.9	2	0.8	4.2	
	B3	48.9	2	1.0	6.7	
	GPS36	33.6	2	1.0	7.4	
16	GPS36	74.8	12	3.5	329.8	
	B3	48.9	12	0.6	0.4	*
	GPS36	62.0	2	1.7	32.0	
	B3	48.9	12	2.8	70.1	
	GPS36	44.4	2	1.2	10.8	
	B3	48.9	12	2.3	22.2	

OBSERVATIONS SUMMARY

- 4 clear nights during 10-16 May 2006
- High Energy Laser (HEL) at 1064 nm through 1.8-metre telescope
- 12 bursts to GPS 36, 12 to OPTUS B3, 1 to B1
- Standardized Brightness (V) varied 0.5 – 695.8 on GPS, 0.4 – 1480.7 for OPTUS. **Huge variation !**
- After rejecting these extremes, the averages give:

Standardized Brightness Ratio $V_{GPS} / V_{OPTUS} = 4.2$

Measured Cross Section Ratio $C_{GPS} / C_{OPTUS} = 0.48$

c.f. Theoretical Cross-Section Ratio **0.43**

CONCLUSIONS

- Thanks to creative use of statistics, experimental ratios agree closely with theoretical predictions.
- It suggests that this might indeed be a viable technique for comparing real cross-sections.
- Alternative measurement schemes might be:

  - Direct measurement of signal strengths (not available at Stromlo – but Optus is!)

  - Conversion of return rates to signal strengths *(see e.g. Appleby & Gibbs (1994))*

MORE EXPERIMENTS ?

- More measurements on GPS (which are now drifting back into night passes at Stromlo).
- OPTUS vs. GIOVE-A (but: where is it?)
- OPTUS vs. GLONASS, including Return Rate method to check on ND-to-Extinction method.
- LLR Brightness Ratio: $V_{GPS}/V_{Apollo15} = 1489$ (corresponding to ND 3.2)
- Encourage other stations to do similar experiments using their available targets and measurement methods.
- Prepare for Galileo, LARES, etc.