Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

7th International Conference
on Electrical Engineering
ICEENG 2010

Design trade-off of a high resolution telescope for a remote sensing satellite

By

Alaa Eddin M. Mohammed* Samy A. Ghoniemy* Ayman M. Mokhtar*
Taher M. Bazan*

Abstract:

In this paper several optical configurations for an orbiting high-resolution panchromatic push-broom camera are presented. The geometric design aspects for different optical sensor systems are discussed. Several optical telescope configurations emphasizing the challenges associated with high resolution imaging are studied. Different case studies and the result of a trade-off analysis, considering not only optical performance but also other aspects such as cost, volume and complexity are presented.

Keywords:

Remote sensing telescope, telescope design, telescope design trade-offs.

1. Introduction:

Getting a high resolution images from space in simple, low cost way without affecting the optical performance of the system is always the main challenge in the field of satellite telescope design [1, 2].
Currently, push-broom imaging technique is one of the best panchromatic scanners for high resolution space imagers [1, 3-6].
The main mission of the space bus determines the overall design strategy and considered the main driving force for optimization and trade-off analysis. Typically, the mission aspects determine the design requirements of both sensor and optics which in turn specify the design aspects of these subsystems.
For the purposes of telescope design, both sensor and optics subsystems are separately sub-divided into smaller sub-systems. Many researchers studied each sub-system in separate such as in [3- 5, 7-11] and [1, 7, 12-16].

---

* Egyptian Armed Forces

For the purposes of telescope design, both sensor and optics subsystems are separately sub-divided into smaller sub-systems. Many researchers studied each sub-system in separate such as in [3- 5, 7-11] and [1, 7, 12-16].

In [3- 5, 7-11], research is mainly focused on the design of telescope sensors and their optimization methods from the points of view of resolution, pixel size, number of active pixels per line, signal integration technique, detector type, and detector performance. Studying and analyzing these researches we can conclude that a 1-D arrays of CCD

detectors with smaller pixel size to allow high ground resolution, large pixel number to allow a large field of view (FOV) without affecting size, mass and volume and based on time delay integration (TDI) is highly recommended for remote sensing compared with 2-D arrays, this leads to larger field of view, and finally allows much greater scanning speeds especially in dark conditions compared with conventional linear sensors without TDI.

In [1, 7, 12-16], researchers focused on the optical system design techniques, approaches and optimization methods. From these trials we concluded that mirrors based techniques are more suitable for large optical systems than refractive lenses based techniques, since the later suffers from different performance degradation effects such as aberrations, larger size, mass and higher cost.

We also concluded that different design approaches such as two, three and four mirrors telescope designs with and without correcting optical elements are possible. However, three-mirror anastigmatic (TMA) configuration showed a suitable image quality, it is rarely used in practice because of the difficulties in its manufacturing and aligning. Also, changing mirrors type and their conic coefficients greatly affects the overall telescope performance; such as in Cassegrain and Ritchey-Chretien(R-C) telescopes.

It is also concluded that more mirrors with more location freedom, such as in Korsch telescope, leaded to better modulation transfer function (MTF) performance but other performance measures such as; design complexity, size, mass and cost are highly degraded.

Finally, two mirrors design with lens correctors can lead to superior performance capabilities with reasonable size, mass and cost

In this paper commercially available 1-D CCD array with TDI technique is employed. In section 2, general optical design parameters of space imaging systems are presented. The analytical design of 2-mirror system is presented in section 3. Design and simulation using ZEMAX software of different telescopes configurations are presented in section 4. Simulation results and analysis depending on the mission requirements are discussed in section 5. Trade-off studies for the selection of the best compromise solution are discussed in section 6. Finally; section 7 presents a conclusion and exclusive summary.

2. General space imaging system optical design parameters:

The general imaging system design parameters including the optics focal length (f), entrance aperture diameter (D), focal number (F/#), instantaneous field of view (IFOV), field of view (FOV) and swath width (SW) are mainly depend on other parameters such as ground pixel size (GRD), satellite orbit altitude (H) and the pixel size (x) as shown in Fig. (1) [3-5].All the design parameters can be analytically derived using Equations (1-6).

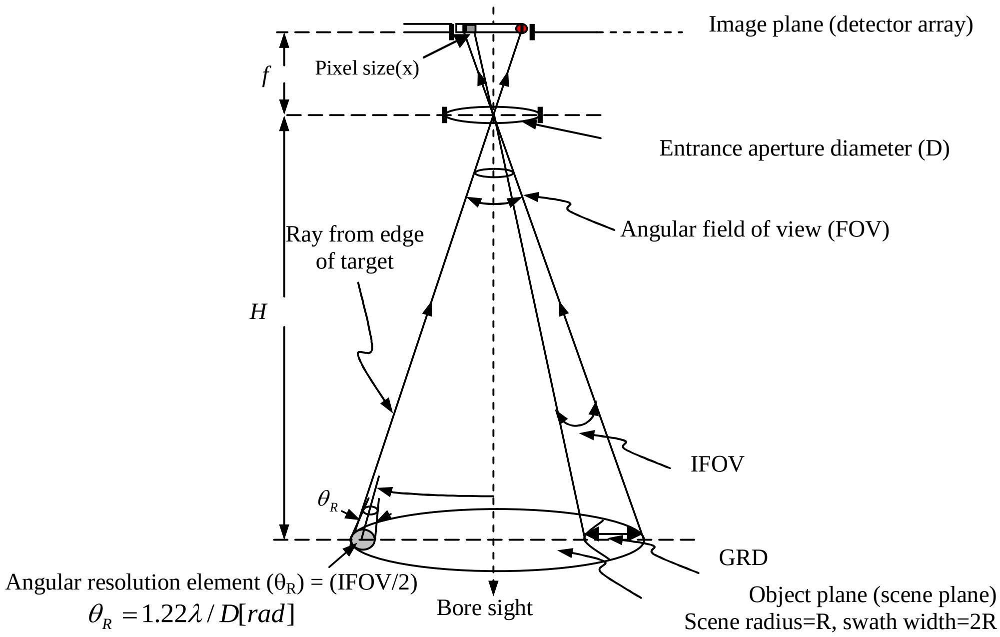

Fig. (1): Optical characteristics of an electro-optical system

$$f = x \cdot \frac{H}{GRD} \tag{1}$$

$$D = \frac{2.44 \cdot \lambda \cdot f \cdot Q}{x} \tag{2}$$

In which, λ is the operating wavelength and Q is the imaging quality factor.

$$F/\# = \frac{f}{D} \tag{3}$$

$$IFOV = 2 \cdot \tan^{-1}\left(\frac{GRD}{2H}\right) \tag{4}$$

$$FOV = 2.\tan^{-1}\left(\frac{L}{2f}\right) \tag{5}$$

In which, L=n.*x*, L is the active line of detectors, n is number of active pixels.

$$SW = H.\frac{L}{f} \tag{6}$$

3. The analytical design of 2-mirror telescope:

The design parameters of such system are radius of curvature of primary mirror (R_1),radius of curvature of secondary mirror (R_2), distance from primary to secondary mirror (d) and back focal distance (b). The parameters are in direct relation with a set of normalized parameters such as obscuration ratio (*k*), ratio of mirror radii of curvature (ρ), transverse magnification of secondary (m) which defined as given in Equations (7-9) [12, 14].

$$k = \frac{y_2}{y_1} \tag{7}$$

In which, y_1 and y_2 are the marginal rays heights of the primary and secondary mirrors, respectively.

$$m = \frac{-s_2^{'}}{s_2} = \frac{f}{f_1} \tag{8}$$

In which, s_2 is object distance of the intermediate object,s'_2 is image distance of the intermediate object and f_1 is focal length of the first mirror

$$\rho = \frac{R_2}{R_1} \tag{9}$$

Using the schematic geometry illustrated in Fig.(2), Equation (10) is derived and given by

$$\frac{1}{s_2^{'}} + \frac{1}{s_2} = \frac{2}{R_2} \tag{10}$$

Equations (8) can be represented by normalized parameters; by the aid of Equations (8-10) and the derived relation $s_2 = {kR_1}/{2}$ (using the schematic geometry illustrated in Fig. (2), and given by

$$m = \frac{\rho}{\rho - k} \tag{11}$$

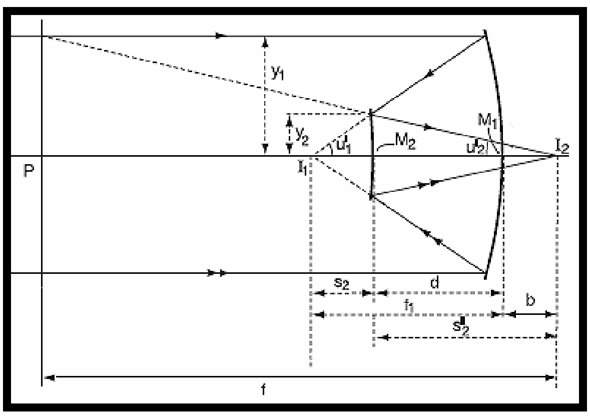

Fig. (2): Schematic diagram of two mirror reflecting telescopes

The design parameters can be analytically derived using the calculated design parameters (*f* and D) in section 2 and choosing the suitable values for obscuration ratio (k) and focal number $(F/\#)_1$ for the first mirror as follows:
The first step in the design is to estimate the marginal ray height of secondary mirror (y_2) using Equation (7), then radius of curvature of secondary mirror (R_2) can be calculated using Equation (8, 9 and 11), finally the distance from primary to secondary mirror (d) and Back focal distance (b) can be estimated using equations (8 and 10) and the schematic geometry illustrated in Fig. (2), and given by

$$d = (1-k)f_1 \qquad (12)$$

$$b = (k(m+1)-1)f_1 \qquad (13)$$

4.Design and simulation of different telescopes configurations

In this section, it is required to determine the best optical configuration that fulfills the requirements of a real push-broom panchromatic scanner given in Table (1). Studying this case, we found that the best performing commercial detector for this system is the Fairchild CCD5061 with a pixel size, *x*=8.75 µm, number of active pixels per line, n=6144 and uses 128 TDI stages.

Table (1):Requirements of the push-broom panchromatic scanner

Spectral bandwidth (panchromatic)	400-700 nm
H	460km
GRD	1.6m
(MTF) of the optics (at Nyquist frequency)	≥30%

In order to determine the best configuration we studied different configurations, for this purpose there are some space imaging system parameters have to be determined analytical. Equations (1-6) are solved using the system requirements presented in Table (1) and leaded to the following telescope design parameters shown in Table (2).

Table (2): Calculated telescope design parameters

f	2.5m
D	0.42m
F/number(system)	≈ 6
IFOV	±1.74 µrad
FOV	±0.6deg
SW	≈ 9900 m

In the rest of this section we will try to study different telescope configurations to find the best configuration that fulfills the two main performance measures to assess the resolution of the telescope which are the MTF and the spot diagrams. The MTF is a quantitative measure of image quality that describes the ability of an optical system to transfer an object contrast to its image.

An MTF relates the working spatial frequency of the optics, in units of line pair cycles per millimeter, to the percentage of the contrast measured from the original image [1]. The MTF at Nyquist frequency, f_{Ny} , is given by;

$$f_{Ny} = \frac{1}{2x} \tag{14}$$

Using the selected CCD sensor parameters (Fairchild CCD5061 with a pixel size of 8.75µm and substitute in Equation (11), the Nyquist frequency, $f_{Ny} \approx$ 57.14 cycles/mm.
As we discussed in section 1, the most effective optical configurations are; Cassegrain, Ritchey-Chretien, korsch and Ritchey-Chrétien with correction lenses. All the configurations are studied analytically, designed, implemented and their performances are analyzed using ZEMAX® software package [17] and presented in the rest of this section.

1) Cassegrain telescope design and simulation using ZEMAX

The Cassegrain telescope distinguished with its comparatively simple, cheap, and easy to design. It has two mirrors, the first is parabolic mirror (M1) with conic coefficient k_1= -1 and the second (M2) is hyperbolic mirror with conic coefficient k_2. Using the calculated telescope parameters in Table (2), suitable values for F/number of 1.64 for the first mirror and obscuration ratio, k ≈0.238, then substituting them in Equations (7- 11) for two mirror telescope, we calculated all the telescope parameters and the results are shown in Table (3). The next step was the design optimization for R_2, k_2 and the distance between M2 and the focal plane (FP) using ZEMAX and results are shown in Table (4). Using the calculated design parameters and the results of optimization in ZEMAX, the simulation results of Cassegrain telescope is illustrated in Fig. (3).

Table (3): Calculated two mirrors telescope design parameters

y_2	≈5cm
m	≈3.6232
ρ	≈0.329
R_2	≈-45.4cm
d	≈52.57 cm
b	≈6.95 cm

Table (4) :The Cassegrain telescope layout using ZEMAX

Surf:Type		Comment	Radius		Thickness		Glass		Semi-Diameter		Conic	
OBJ	Standard		Infinity		Infinity				Infinity		0.000000	
1*	Standard		-45.383702		52.571100				0.000000	U	0.000000	
STO*	Standard		-138.000000		-52.571100		MIRROR		21.016760		-1.000000	
3*	Standard		-47.391058	V	53.572500	V	MIRROR		5.599703		-3.551775	V
IMA	Standard		Infinity						2.390796		0.000000	

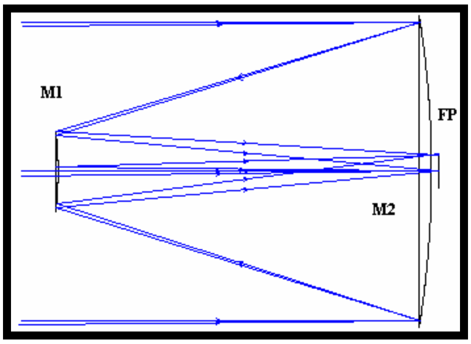

Fig. (3): A Zemax simulation of the Cassegrain telescope

2) Ritchey-Chrétien telescope (R-C) design and simulation using ZEMAX

In order to further reduce the off axis aberration and get better image quality, we studied the optical configuration of the Ritchey-Chrétien telescope. It employs two hyperbolic mirrors with conic coefficients k_1 and k_2. Using the same parameters in Table (3), and the results of optimization for R_2, distance between M2 and FP, k_1 and k_2. The R-C telescope layout using ZEMAX is shown in Table (5) and its schematic design is illustrated in Fig.(4).

Table (5) : The R-C telescope layout using ZEMAX

Surf	Type	Comment	Radius		Thickness		Glass		Semi-Diameter		Conic	
OBJ	Standard		Infinity		Infinity				Infinity		0.000000	
1*	Standard		-45.383702		52.571100				0.000000	U	0.000000	
STO*	Standard		-138.000000		-52.571100		MIRROR		21.016754		-1.058777	V
3*	Standard		-47.391058	V	53.572773	V	MIRROR		5.610689		-4.292469	V
IMA	Standard		Infinity						2.376920		0.000000	

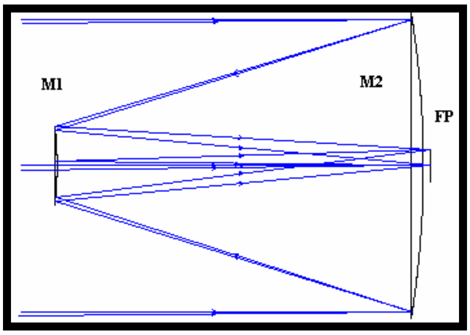

Fig. (4) :A Zemax simulation of the R-C telescope

After simulation we notice that the conic constant for the secondary mirror is more negative than for the Cassegrain, The total track of the R-C telescope is approximately the same as Cassegrain telescope

3) *Korsch telescope design and simulation using ZEMAX*

Korsch telescope consists of four mirrors (three aspheric mirrors and one flat folding mirror). Increasing two optical elements (fold mirror and tertiary mirror) leaded to better image quality due to more available degrees of freedom. Using the same parameters in table (3), and results of optimization of initial values for R_3, conic coefficient of third mirror (k_3) and distance between M2, third mirror (M3), fold mirror (FM) and FP, the proposed Korsch telescope layout using ZEMAX is shown in Table (6). Figure (5) illustrates the simulation results of the proposed Korsch telescope using ZEMAX software.

Table (6): The Korsch telescope layout using ZEMAX

Surf	Type	Comment	Radius		Thickness		Glass		Semi-Diameter		Conic	
OBJ	Standard		Infinity		Infinity				Infinity		0.000000	
1*	Standard		-45.383702		52.571100				0.000000	U	0.000000	
STO*	Standard		-138.000000		-52.571100		MIRROR		21.016764		-0.951009	V
3*	Standard		-45.383702		82.000000	V	MIRROR		5.586273		-2.602753	V
4	Standard		-30.017716	V	-23.000000	V	MIRROR		5.292165		-0.664525	V
5	Coord Break				0.000000		-		0.000000			
6	Standard		Infinity		0.000000		MIRROR		2.410696		0.000000	
7	Coord Break				22.176109	V	-		0.000000			
IMA	Standard		Infinity						5.423777		0.000000	

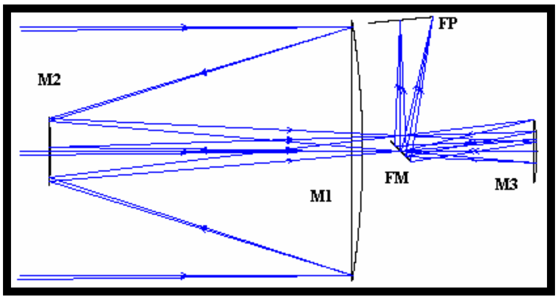

Fig. (5) :A Zemax simulation of the Korsch telescope

After simulation we notice that the conic constant for M1 and M3 is ellipse while M2 is hyperbolic, and The total track of the Korsch telescope is larger than the Cassegrain telescope and the R-C telescope.

4) *R-C telescope with correction lenses design and simulation using ZEMAX*

To get a compact design with a good image quality, the Ritchey-Chrétien design was employed after compared with other two mirrors telescope designs based on its superior aberration correction capabilities, and to reduce the residual aberrations in FP we need more available degrees of freedom. Using the same parameters in table (3), the design is optimized by employing two lenses corrector elements (L1,L2) and made of commercially available materials from the Schott catalog (BK7and SF4 glasses) [18]. Then ZEMAX is used for the optimization of initial values for R_3, R_4, R_5, R_6, K_1, K_2, thickness of (L1, L2) and distance between M2, L1, L2 and FP. The proposed R-C telescope with correction lenses layout using ZEMAX is shown in Table (7). The complete R-C telescope with correction lenses design based on the results presented in Table (7) and using ZEMAX software is illustrated in Fig. (6).

Table (7): The R-C telescope with corrector lenses layout

Surf	Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic
OBJ	Standard		Infinity	Infinity		Infinity	0.000000
1*	Standard		-45.333702	52.571100		0.000000 U	0.000000
STO*	Standard		-138.000000	-52.571100	MIRROR	21.016756	-1.043364 V
3*	Standard		-45.333702	54.000000 V	MIRROR	5.603517	-3.584572 V
4*	Standard		7.938505 V	0.235657 V	BK7	2.850306	0.000000
5*	Standard		6.131300 V	2.500000 V		2.789214	0.000000
6*	Standard		5.356370 V	2.393388 V	SF4	2.821854	0.000000
7*	Standard		4.413757 V	1.065334 V		2.267504	0.000000
IMA	Standard		Infinity			2.266833	0.000000

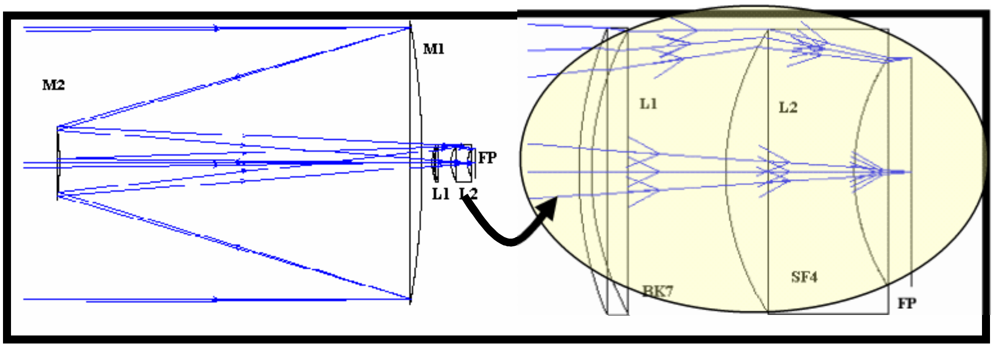

Fig. (6): A Zemax simulation of the R-C telescope with corrector lenses

After simulation we notice that the conic constant for M1 and M2 is not the same as in the R-C telescope without corrector lenses, and the total track of the R-C telescope with corrector lenses is nearly the same as in the Cassegrain telescope and the R-C telescope and not large as in the Korsch telescope.

5.Simulation results and analysis

1) Cassegrain telescope

According to the design and simulation of the Cassegrain telescope as discussed in section 4.(1).Figures (7) and (8) show spot diagrams and MTF for on axis and marginal FOV of Cassegrain telescope.

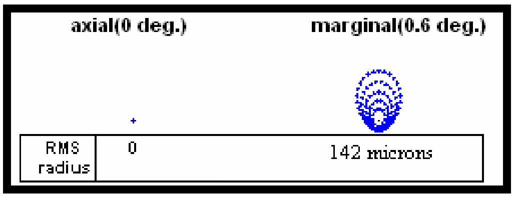

Fig. (7) :Cassegrain telescope spot diagram using ZEMAX

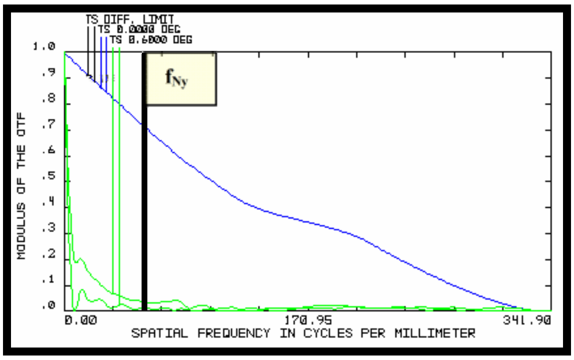

Fig. (8): Cassegrain telescope MTF using ZEMAX

From Figures (7) and (8) we concluded that the total track of the system is 53.5725 cm, the on axis FOV has good image quality with zero RMS radius and MTF (f_{Ny}) value > 70%, but off axis marginal FOV suffer from coma aberration with RMS radius value of 142 microns which is much larger than the required pixel size, and its MTF (f_{Ny}) value <0.05%. So Cassegrain telescope has the ability to correct only spherical aberration.

2) *Ritchey-Chrétien telescope (R-C)*

According to design and simulation of the R-C telescope as discussed in section 4.(2). Figures (9) and (10) show spot diagrams and MTF for on axis and marginal FOV of R-C telescope, while Fig. (11) shows the tangential (T) and sagittal (S) surfaces.

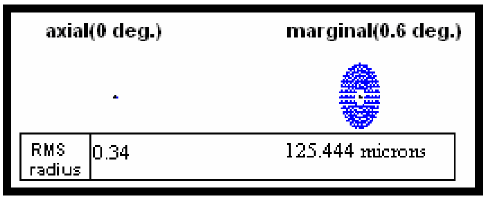

Fig. (9): R-C telescope spot diagram using ZEMAX

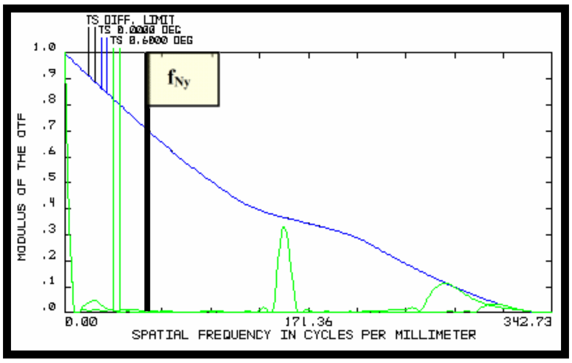

Fig. (10) :R-C telescope MTF using ZEMAX

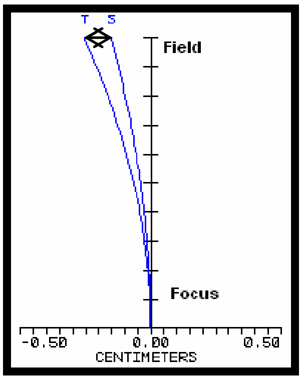

Fig. (11) :R-C telescope tangential and sagittal surfaces using ZEMAX

From Figures (9) and (10) we concluded that the total track of the system is 53.5728 cm, the on axis FOV has good image quality with RMS radius = 0.34 microns and MTF (f_{Ny}) value > 70%, but off axis marginal FOV suffer from astigmatism with RMS radius value of 125.4 microns which is much larger than the required pixel size, and its MTF (f_{Ny}) value <0.006%. So R-C telescope has the ability to correct both coma and spherical aberration but suffers from astigmatism and the curvature of image surface. We also concluded from Fig. (11) that R-C telescope gives approximately 0.1 cm difference between tangential and sagital surfaces which degrades the overall performance of this system.

3) Korsch telescope

According to the design and simulation of the Korsch telescope as discussed in section 4.(3). ZEMAX is used to predict spot diagrams and MTF for on axis and marginal FOV of Korsch telescope as shown in Figures (12) and (13). Also, it is used to show the coincidence between T and S surfaces and how Korsch telescope overcome the residual aberrations as shown in Fig. (14).

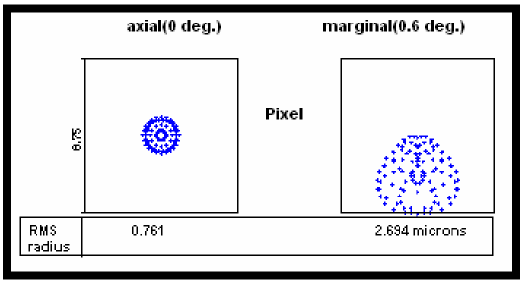

Fig. (12) :Korsch telescope spot diagram using ZEMAX

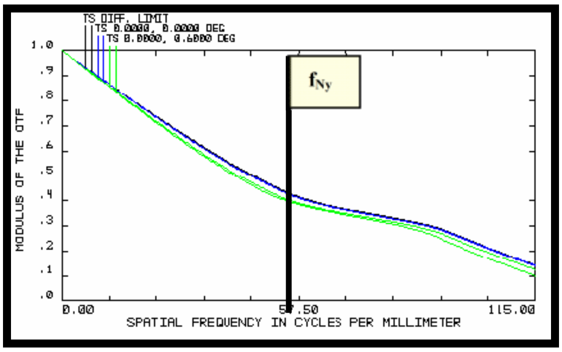

Fig. (13) :Korsch telescope MTF using ZEMAX

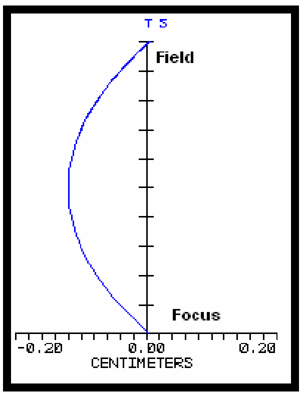

Fig. (14): Korsch telescope tangential and sagittal surfaces using ZEMAX

From Figures (12) and (13) we concluded that the total track of the system is 82 cm, the on axis FOV has good image quality with RMS radius = 0.761 microns which is inside the pixel size and its MTF (f_{Ny}) value ≈ 0.4, where the off axis marginal FOV has good image quality with RMS radius = 2.694 microns which is also inside the pixel size and its MTF (f_{Ny}) value ≈ 0.39. Therefore, we can conclude that Korsch telescope has the ability to solve the aberration problems exist in Cassegrain telescope and R-C telescope. We also concluded that this telescope configuration and design leaded to a complete coincidence between T and S surfaces which make it suitable for the current requirements. After studying the Korsch telescope we noticed that this telescope has a very good off axis image quality but the longitudinal size of the system is much larger than in the previous cases which increase mass, volume and cost.

4) R-C telescope with corrector lenses

According to the design and simulation of the R-C telescope with corrector lenses as discussed in section 4.(4), and using ZEMAX, Figures (15) and (16) show spot diagrams and MTF for on axis and marginal FOV of this telescope. While Fig. (17) shows the approximate coincidence between T and S surfaces at marginal FOV.

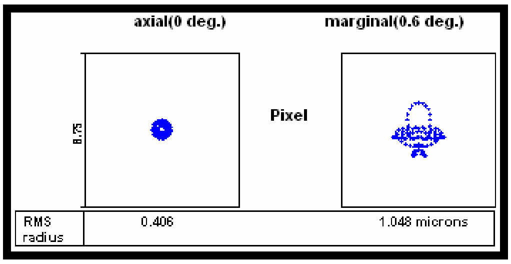

Fig. (15) :R-C telescope with corrector lenses spot diagram

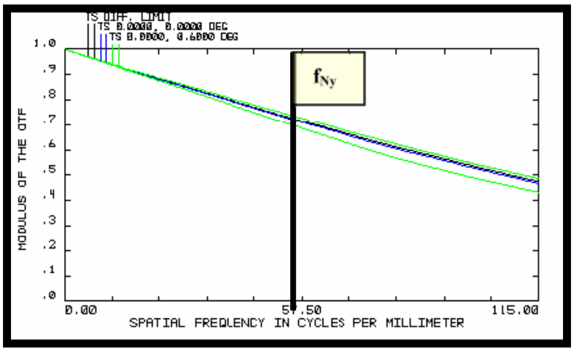

Fig. (16): R-C telescope with corrector lenses MTF

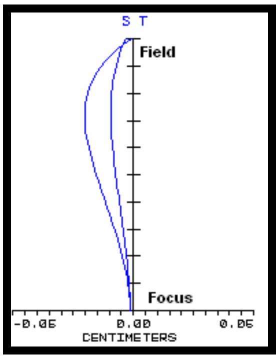

Fig. (17) :R-C telescope with corrector lenses tangential and sagittal surfaces

From these figures we concluded that the total track of the system is 60.2 cm, the on axis FOV has good image quality with RMS radius = 0.406 microns which is inside the pixel size and its MTF (f_{Ny}) value > 0.7, where the off axis marginal FOV has good image quality with RMS radius = 1.048 microns which is also inside the pixel size and its MTF (f_{Ny}) value > 0.7.So we can conclude that the telescope has the ability to solve the aberration problems exist in Cassegrain telescope and R-C telescope but it has a large value of MTF (f_{Ny}) .

6.Trade-off study for the selection of the best compromise solution

The driving parameters which used for the trade-off in order to select the best compromise solution are image quality (MTF at the Nyquist frequency and the spot diagrams), complexity (number of optical surfaces), the longitudinal and transverse size of the telescope, mass (volume of the optics) and cost (shape and size of the surface).
Taking all together, the design results presented in section 4 and the simulation results presented in section 5, these parameters are summarized in Table (8) for the studied four optical configurations.

Table (8):derived parameters for each optical configuration

	Cassegrain	R-C	Korsch	R-C with correctors
MTF(f_{Ny})	<30%	<30%	>30%	>30%
Spot diagram	out pixel	out pixel	inside pixel	inside pixel
Complexity	2	2	4	4
Size	medium	medium	large	medium
Mass	small	small	medium	medium
Cost	low	low	large	medium

According to Table (8), Cassegrain telescope and R-C telescope are very suitable from the point of view of complexity, size, mass and cost but unsuitable from image quality point of view. Korsch telescope is very suitable from image quality point of view but has more mass, size, complexity and cost. Finally, R-C telescope with corrector lenses showed very suitable image quality**,** size and has an acceptable increase in mass and cost but it is unsuitable from the complexity point of view. Therefore, we can conclude that R-C telescope with corrector lenses is the optimal configuration for image quality, complexity, size, mass and cost.

7.Conclusion

In this paper, the design, implementation and analysis of four different telescope designs for remote sensing satellite are studied using ZEMAX software package. Optimization of each design was also performed using the same package. Trade-off study was performed to determine the optimum telescope configuration. We conclude that the best compromise optical configuration is R-C telescope with corrector lenses. Korsch telescope is considered a good optical configuration except its long size with respect to others. Finally both Cassegrain and R-C telescopes need corrector lenses to get high image quality that fulfill the requirements.

References:

[1] Thomas H. Zurbuchen et al., “A Low-Cost Earth Imaging Telescope.” IEEE Proceedings, IEEEAC paper #1430, Version 5, 2007

[2] Thomas H. Zurbuchen et al., “Low-Cost Earth Imaging System for Novel Commercial Applications.” IEEE Proceedings, IEEEAC paper #1428, Version 3, 2007

[3] Rainer Sandau, *Digital Airborne Camera, Introduction and Technology*. Springer, 2010.

[4] Wiley J. Larson and James R. Wertz, *Space Mission Analysis and Design*. Kluwer Academic Publishers, 3rd ed., 1999.

[5] Rainer Sandau and Klaus Brieb, “System Design Aspects of a Spaceborne Wide-Angle Optoelectronics Stereo Scanner.” In the Proceedings of ISPRS Symposium , Italy, 1994

[6] R. Reulke et. al., “Determination and Improvement of Spatial Resolution of the CCD-Line-Scanner System ADS40,” ISPRS Journal of Photogrammetry Remote Sensing, vol. 60, p. 81–90, 2006.

[7] Andrew Cawthorne, David Purll and Stuart Eves, “Very High Resolution Imaging Using Small Satellites.” In the Proceedings of 6th Responsive Space Conference, Los Angeles, 2008.

[8] Ian S. Mclean, *Electronic Imaging in Astronomy, Detectors and Instrumentation*. Springer, 2nd ed., 2008.

[9] Steve B. Howell, *Handbook of CCD Astronomy*. Cambridge University Press, 2nd ed., 2006.

[10] Jan T. Bosier and Inge M. Peters, “Technical Challenges and Recent Progress in CCD Imagers.” In the Proceedings of Nuclear Instruments and Methods in Physics Research, vol. A 565, p. 148–156, 2006

[11] George Joseph, *Fundamentals of Remote Sensing*. Universities Press, 2003.

[12] Daniel J. Schroeder, *Astronomical Optics*. Academic Press, 2nd ed., 2000.

[13] Giulia Pica et al., “High Resolution Deployable Telescope for Satellite Application.” In the Proceedings of Spie’s Remote Sensing, Europe, 2003.

[14] Pierre Y. Bely, *The Design and Construction of Large Optical Telescopes*. Springer, 2003.

[15] Marija S. Scholl, Gonzalo P. Padllla and Yaujen W.Wang, “Design of a High-Resolution Telescope for an Imaging Sensor to Characterize a (Martian) Landing Site,” Journal of Optical Engineering, vol. 34,no.11, pp. 3222-3228, 1995.

[16] M. Lampton and M. Sholl, “Comparison of On-Axis Three-Mirror-Anastigmat Telescopes.” SPIE Proceedings, 2007.

[17] ZEMA*X*, Optical design program User's Guide, Version 9, 2000.

[18] SCOTT North America, Inc., “http://www.us.schott.com/advanced_optics/english/ our_products/materials/data_tools/index.html.”