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# SIGNAL TO NOISE RATIO OF IR SEEKER WITH A NEW OPTICAL FRACTAL MODULATOR

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***Abstract:***

*The signal-to-noise-ratio (SNR, S/N) is a technical term used to characterize the quality of the signal detection of a measuring system It is an important factor to check the quality of control system, Present work contains evaluate the S/N for the seeker with a new modulator that design by fractal function for IR band, and the results compared with the same seeker with a normal modulator. The advantage of this research that the modulator is a new design using a fractal function.*

*This research describes the algorithms of Signal to Noise Ratio for the infrared seeker with Optical Fractal modulator compared with the seeker which has a normal modulator; the results were discussed and analyzed to design an optical modulator; which consists of two pattern circles. In our case, the standard well known as (S/NR) definition denoted as the global Signal for Noise Ratio of as (GS/NR). The OTF (Optical transfer function) and MTF (Modulation Transfer Function) has been calculated to find the ability to transmit the optical signal. The present technique compared with the technique used with a system using a CCD camera image sensor [13].*

***Keywords:*** *IR Seeker - SNR- Optical modulator – GSNR - Opto Electronic system- coding element*

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**Introductions:**

IR modulator is an important part of a seeker, which is responsible for modulation. The seeker is a sub-system of many control systems which is a control unit (an Opto - Electronic system), The Robot, Aircraft, Satellite Aerospace Rocket, and some Guided Missiles Seeker has the following sub-system, as shown in fig (1).

a- Optical sub-system (such as Lenses, Mirrors, Dome, Filters, Prism, and Optical Modulator).
b- Electrical and Electronic sub-system.
c- Mechanical sub-system.

The main sub-system is the Optical Sub-System and the main component of this optical system is the Optical Modulator (coding element). The Present research (S/N R) calculate accumulative SNR for all the subsystems for the seeker. The (S/N R) of the seeker had been evaluated twice, first with FM (Fractal Modulator) normal optical modulator and the other with Fractal Optical modulator, where both of them are IR material.

The present paper aims to investigate the efficacy of the new optical modulator (Fractal Modulator) on the S/NR value of the seeker. The S/NR results of seeker were compared with normal optical modulator and with a Fractal optical modulator.

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The present technique I seared the S/N R by evaluating the frequency while the reference paper [13] used the intensity of imaging of CCD camera it is a deferent technique with the same result which S/N R.

**Modulator design:**

According to the pattern, the modulator design can be divided into two types:

Normal modulator [1]

This modulator (on the shelf) looks like a disc with some equal radial angle scatters .and it may be FM (fractal modulation), AM (Amplitude modulation) or PM (phase modulation). The modulation in our case it is FM modulation, as shown in fig. (2).

Fractal modulator [2]

This modulator has been designed by using Fractal function as following:

Let (H(x), h (d)) be a metric space, and $f(x) > x$ be a function, and $s \sqsubset x$, then: $f(s) = \{ f(x): x \sqsubset s\}$

The function f is one-to-one.

If $x,y \in x$, and $f(x) = f(y)$, so $x = y$, then the metric space can be given by the equation:

$A = TA$

Where A is a point in the initial area and A' is a new point in under matrix operation (T).

The matrix (T) is given by:

$$T = a\ b\ c\ d$$

The transformation (W) in the Euclidean plane can be given by [4, 6]:

$$w(x,y) = (ax + by + e, cx + dy + f)$$

The points (a, b, c, and d) define rotation and scaling operations to be applied to the point and are called affine transformation. The (e and f) points define a translation to be applied to the point. The transformation (W) can be defined in this formula [8-10]:-

$$w(x) = w\ \ x\ y\ \ = a\ b\ c\ d\ \ x\ y\ \ +\ \ e\ f$$

Or $W(x) = Ax + T$

Where:

Ax = the matrix $a\ b\ c\ d\ \ \ x\ y$

T= the horizontal vector $e\ f$

By using this concept and its kit program, we have designed an optical modulator as shown in Fig. (3-a). This optical modulator consists of two pattern circles; each circle is divided into ten transparent and ten opaque sectors (q).

The first pattern is designed in a circle with a radius of (0.1 cm) located in the first third of the Reticle, i.e. the maximum distance of this pattern is equal up to (3 cm). After conducting the operations of scaling, rotation and iteration we have got a pattern as shown in Fig. (3-b) while Table (1) represents the data of the first pattern.

The second pattern is designed in an equilateral triangle of side length (0.1 cm) within the last third of the disk, the maximum points of this pattern are equal up to (9 cm), where we left a blank space in the middle (3 cm) length, i.e. starting from a distance of (6 cm) for the second pattern, after conducting the operations of scaling, rotation, and iteration we have got a pattern as shown in Fig (4),

S/N Ratio Algorithm Description

The standard SNR definition for any system (such as seeker system) denoted as global SNR (GSNR) is defined as:

$$10\ \frac{\sigma\ s\ 2}{\sigma\ 2\ n}$$

Where (σs) is the power of the signal and (σn) is the power of noise. The estimated value of seeker (S/NR) is getting from a different subsystem, to Measure the (S/NR) for Reticule (Modulator) we can use the following equation:

$$\frac{S}{N} = \sqrt{\frac{\pi}{4}}\ J(\gamma) \left[\frac{J_{atm}(\gamma)}{\Omega'^2}\right] \left[\frac{D'\ BR\eta\ wr}{d}\right] \left[\left[\frac{1}{\sqrt{BW}}\right] Ks\right] \left[\frac{D_e}{\theta\ (FN)}\right] \eta^2 c\ \eta_{cl} m_{is}\ J_{oe}\ \ f\ K_{OR} \ldots.\ (1)$$

Where it contains several parts as follow:

S/N of seeker = part (1) + part (2) + part3) + part (4) + part (5)
Where:
Part (1) for Irradiance target:

$$\frac{S}{N} = \sqrt{\frac{\pi}{4}} * J(\gamma)$$

Part (2) For Detectors:

$$\left[\frac{D^{'}\ BR\eta\ wr}{d}\right]$$

Part (3) For Electronic:

$$\left[\frac{1}{\sqrt{BW}}\right] Ks$$

Part (4) for range /atmosphere transmittance:

$$\left[\frac{J_{atm}(\gamma)}{\Omega^{'2}}\right]$$

Part (5) for Optics:

$$\left[\frac{D_e}{\theta\ (FN)}\right] \eta^2 c\ \eta_{cl} m_{is}\ J_{oe}\ \ f\ K_{OR}$$

Where each element of the parts is:
BW: the signal bandwidth.
e: Electron charge.
Rd: Detector resistance.
η: Filed of View F.O.V. (in radians).
F.O.V. in Stereo radiance.
R: Responsively (A/W).
Pi: Incident Power
tr: (Reticule Transparent Area) / (Reticule Total Area) =Reticule Transparency Factor
Ra: Detector Responsively (A/W), for the Back Ground Energy
J : Target Irradiance.
Dc: Collecting Diameter of Optics (Dome)

$$\frac{S}{N} = \frac{\pi}{2}\ \frac{(\tau_a \tau_0\ NA.D.D^*}{R^2} \left[\frac{V.C}{\Omega^{'}}\right] \ldots (2)$$

R: the range in (cm).
J: Radiant Intensity $\ldots$ WStr $- 1 = \frac{P\ (power)}{4\pi}$
$\tau_a$ : Atmospheric transmission.
$\tau_0$: Optical system transmission
NA: Numerical aperture of the optical system.
D: Aperture of the system in (cm).
$D^*$: Detectives power of the detector.
V: visibility of the signal.
C: Number of detectors.
$\Omega^{'}$: $\frac{FOV}{times\ of\ scanning}$
From equation (2) above, the reticule transmittance factor is K0R so:

$$K_{oR} = \frac{Real\ Transmittance\ Area}{2al\ \ Area\ of\ the\ Rectal} = \frac{Sector\ Area * no.\ of\ Sectors}{\pi\ r^2} \ldots\ldots(3)$$

We assumed that the parameters of equation 1 above are constant unless the value of K0R (because all subsystems of the seeker are same, it changed the modularity only) so
S/N = (constant) KoR ----------- (4)

Where:

$$\text{Constant} = \sqrt{\frac{\pi}{4}}\, J(\gamma) \left[\frac{J_{atm}(\gamma)}{\Omega'^2}\right] \left[\frac{D' BR\eta\, wr}{d}\right] \left[\left[\frac{1}{\sqrt{BW}}\right] Ks\right] \left[\frac{D_e}{\theta\,(FN)}\right] \eta^2 c\, \eta_{cl} m_{is} J_{oe}\ f \ldots \quad (5)$$

Therefore, we have two values of the parameter (KoR) one for the normal modulator and the other for the fractal modulator.

Result and discussion:

Both modulators have the same size, shape (look like disc its diameter 3mm) and area (4.7 mm2) but different patterns. To find the ability to transmit the optical signal, it has been calculated the OTF (Optical transfer function) and MTF (Modulation Transfer Function) [ 10] the result was approximately being the same that means the same amount of transmitting an optical signal as shown in fig (5,6) [ 10].

**Conclusions:**

a- The (S/NR) is an optimal criterion of seeker function, it gives us the indicator of the output signal operation.
b- The evaluating of (S/NR) of a seeker depends on many subsystems (such as optical, electrical, mechanical systems, etc.).
c- The modulator effective value of (S/NR) is very small because this value is a small part of the optical subsystem.
d- The (S/NR) for both modulators (Normal & Fractal) are the same because they have the same size and amount of optical signal transmitting.

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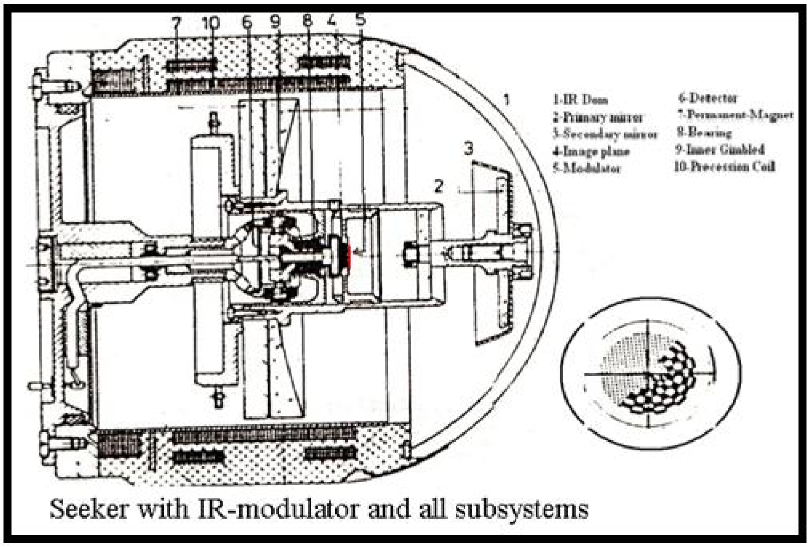


Fig (1-a): Shows diagram of Seeker subsystems.

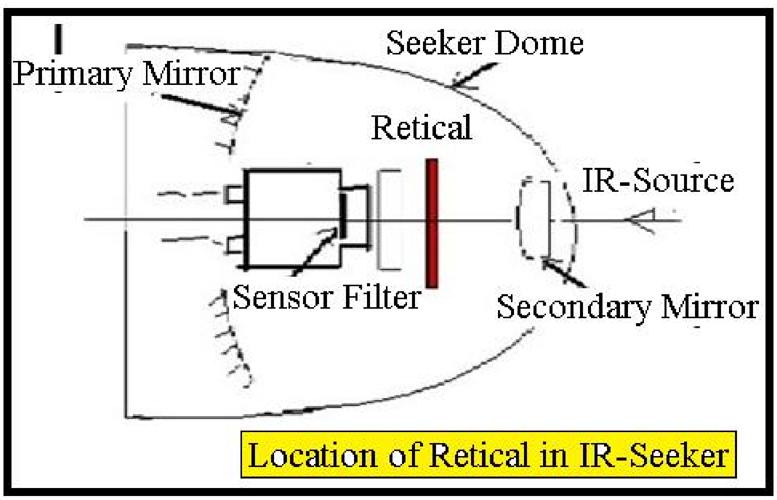


Fig (1- b): The location of the reticle in IR - seeker

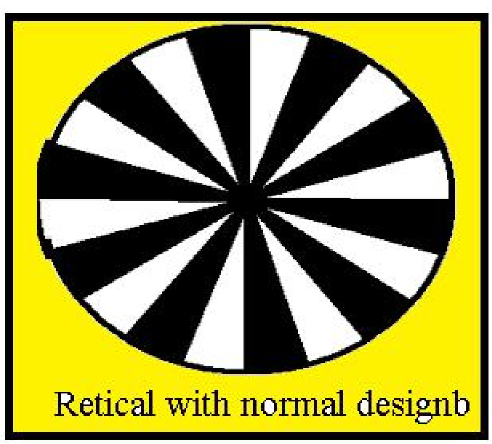


Fig. (2): The Reticle with normal design

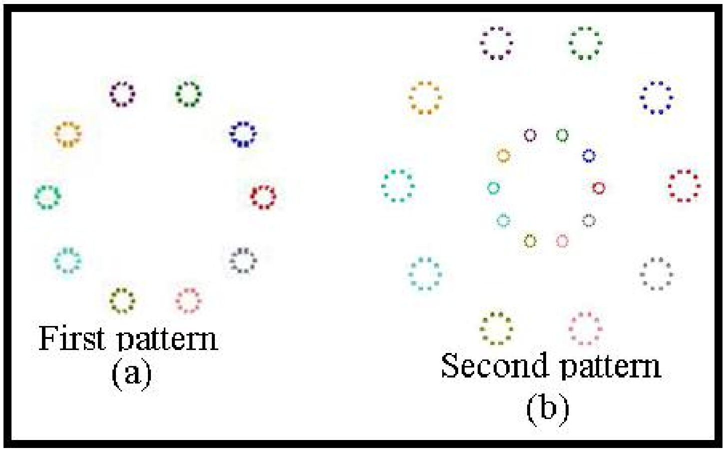


Fig (3- a): The first pattern after 10 iterations (3-b): The second pattern after 10 iteration

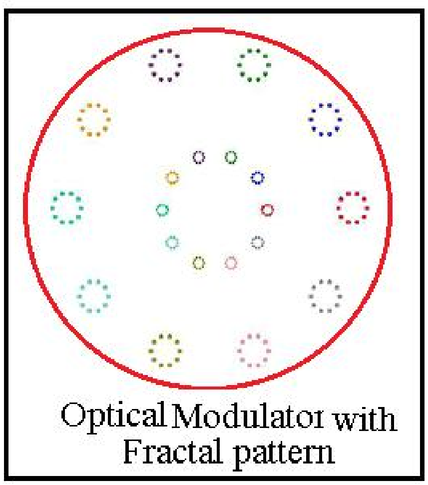


Fig (4): The Fractal Modulation.

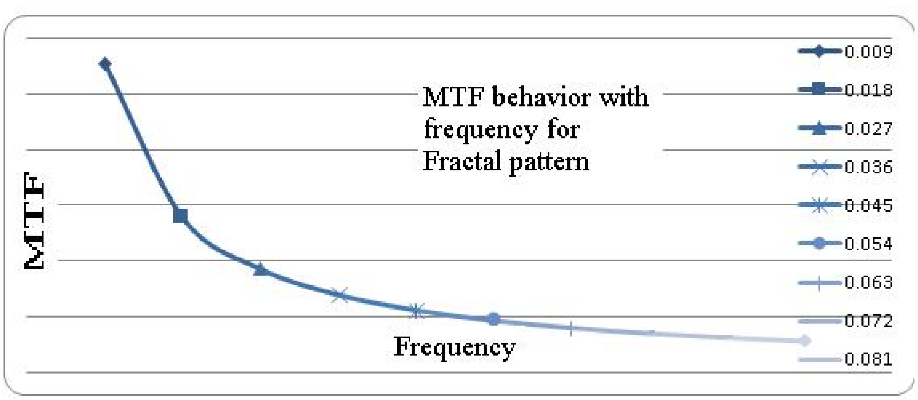

Fig (5): Fractal Reticle (pattern 2), MTF repeats itself and decreases with increasing frequency.

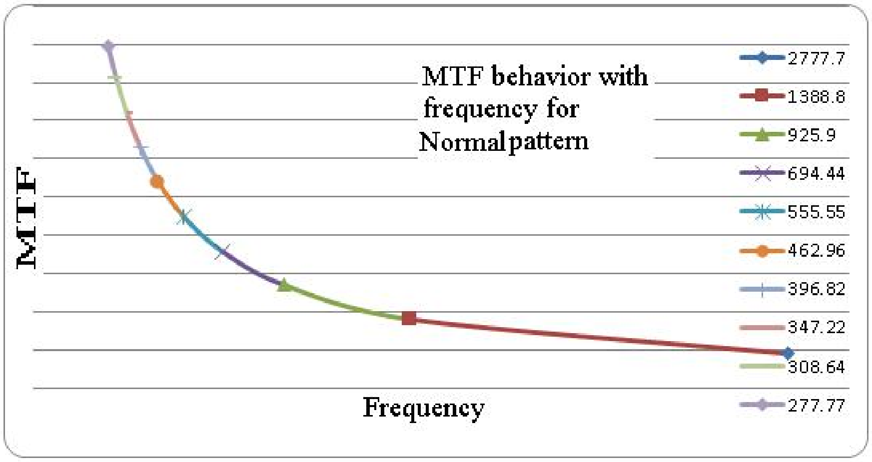


Fig (6): Normal Reticle, MTF decreases with increasing frequency