THE EFFECT OF THE HEIGHT AND SPEED OF THE AIRPLANE CARRYING THE FOCUSED SYNTHETIC APERTURE RADAR ON THE AZIMUTH RESOLUTION

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Abstract:

Airborne imaging radar systems are known by their ability to produce high resolution images of ground targets using microwave region of electromagnetic waves. There are many military and civilian applications of imaging radar systems. The high resolution images achieved by transmitting a number of electromagnetic pulses to the earth surface then integrating them coherently at the receiver. A study have been achieved to show the effect of changing speed or height or both of the airplane carrying the focused synthetic aperture radar upon the azimuth resolution. The simulation results showed that increasing the speed or decreasing the height of the airplane will improve the azimuth resolution, and it can be noted for practical parameters that decreasing the speed and the height of the airplane leads to degraded azimuth resolution. The results of azimuth resolution obtained from simulations and those from theoretical calculations are nearly identical for targets of point reflectors.

قبل في ٢٠٠٥/٤/١١ استلم في ٢٠٠٤/٨/١٤

Introduction:

[illegible] (Side Looking Airborne Radar-SLAR) [illegible] .[1-4] [illegible] (Real Aperture Radar-RAR) [illegible] . (Synthetic Aperture Radar-SAR) [illegible] (Synthetic Aperture) [illegible] .[1,2] [illegible] (pulse compression) [illegible]

Azimuth Processing

[illegible] (SAR) [illegible] (1) [illegible] (2N+1) [illegible] $T\equiv(0,r,\theta)$ [illegible] $n=-N.....N$ [illegible] $S\equiv(x=nd,r=0)$ [illegible] :[1,3] [illegible]

$$L=\frac{\lambda r}{D} \qquad ....(1)$$

[illegible]

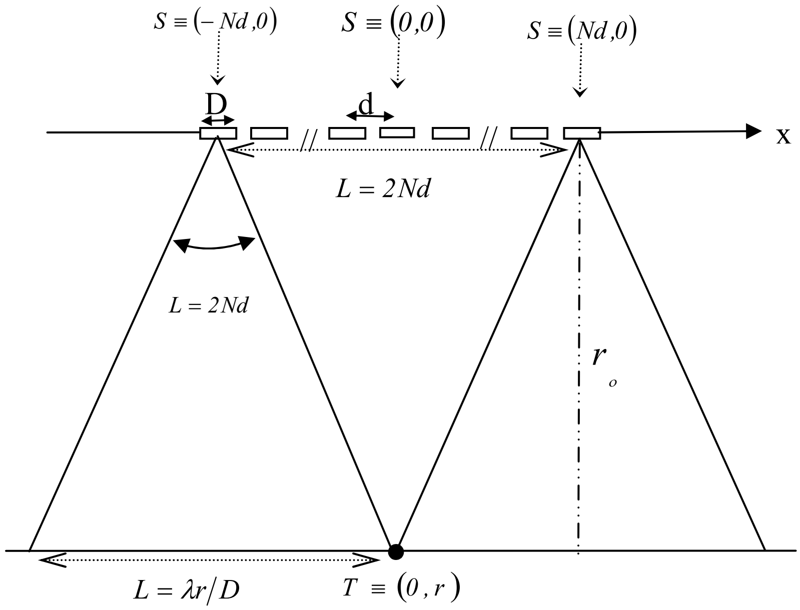
:[1] $e^{-jw_o\frac{2r}{c}}$ [illegible] $r\approx r_o+\left(\frac{nd}{2r_o}\right)$ [illegible] r [illegible]

$$f(nd)=e^{-jw_o\frac{2r_o}{c}-j\frac{2\pi}{\lambda r_o}(nd)^2} \qquad ....(2)$$

[illegible] (2) [illegible]

$$f(nd)=e^{-j\frac{2\pi}{\lambda r_o}(nd)^2} \qquad ....(3)$$

ƧŏƺƙdžƼ (nd) ƥżŏ .ýŏƼơƘ!ƒ ƒƦNj Ŏ5 ǻŏƪƓƪ ƥżŏ Ů ĭƦ!ƒĂ $e^{-jw_o 2r_o/c}$ ƘhƓĂ!ƒ ýdžƓż!ƒ ýƓdžNjƺ Džƙ Ʀƺ
.(x-ŎƛƒƥơŬƉ) ǉƧƓƪdž ýĂƱ ĬƼƵ SAR DžƓƲǉ ŎƒƒĂnj! (discrete variable)ƴƱƖdž!ƒ



.(**x , r**) ăNjƗƨDžƖƐ Ĭƺ hƴƓƯƬDžƖƐ hƟƗƐ ƥƐƭƐƥ hƺNjƧƬDž :(**1**) üƖƪƐ

ƔƞĂdžƕ ƝƓżƙ ƖƦ ƥżƕ Džƛ ƧŏĂƮƘ!ƒ ƗdžĂƲǉdž ƖƧƗƒƦ Ŏ5 (3) Ɨ!ƥƓżdž!ƓƕƗƛdždž!ƒ ƖƧƓƬŰƒ ǇƨƤ Džƙŏ
ƉƥƕdžDžƥƤƘƪŏ Ƙdžƪ!ƒ ƖƧƓƬƺ ƗƞƓżdž!Ă . $L = 2Nd$ ýĂƱƕ (ŎƒƒĂNj ƗƼĂƼƮdž ƾƥƉ ýƗƬƕ ĂƉ) ŎƒƒĂNj ƔŏƗƧƙ
ǇƵ ƧƕżŏĂ (Azimuth Reference Function) Ƙdžƪ!ƒ ýƞƧdž!ƒ Ɨ!ƒƥ ýdž (convolution) ƧƓƼƙ!Ůƒ
:Ɨ!ƥƓżdž!Ɠƕ Ɨ!ƒƥ!ƒ ǉƦNj

$$g(nd) = e^{j\frac{2\pi}{\lambda r_o}(nd)^2} \qquad \ldots\ldots\ldots\ldots(4)$$

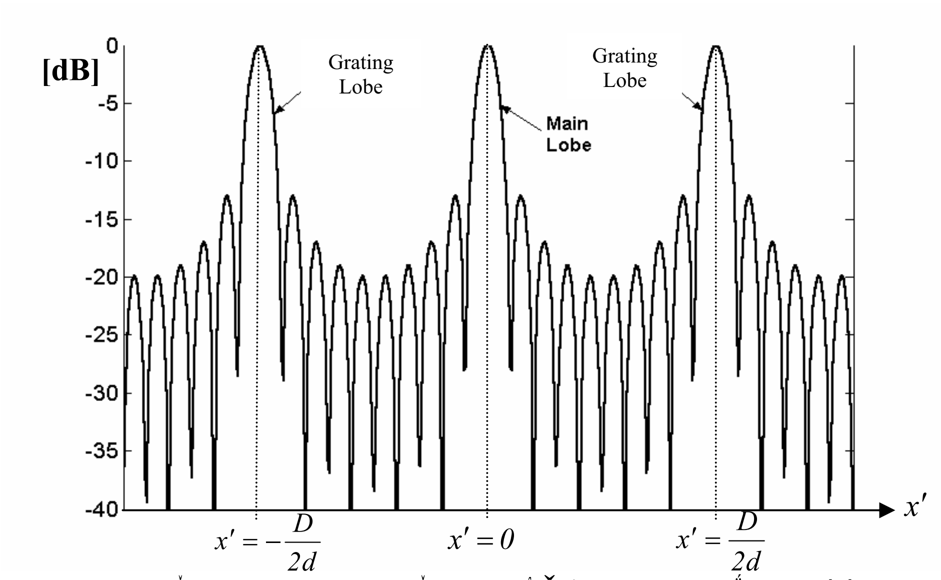
Ă $n \rangle 0$ ǇĂƗƙ ƓdžƥǉƺƼ (4) Ă (3) ǇŏƙƥƓżdž!ƒ ǇŏƕƴƱƖƙdž!ƒ ƳĂǉ!ƒ ǇDž ǇĂƗŏƪ Ɨ!ƓơƘ!ƒ ǉƦNj Ŏ5 ƧƓƼƙŮƒĂ
:[1] ƱŏƪƕƘ!ƒ ƥżƕ ƝƘǉŏƪ $nd \langle\langle L$

$$f(x') = \frac{\sin\left(\frac{2\pi L}{D}x'\right)}{\frac{L}{d}\sin\left(\frac{2\pi d}{D}x'\right)} \qquad \ldots\ldots\ldots\ldots\ldots(5)$$

.Ƙdžƪ!ƒ ǉƓƞƙƒ Ŏ5 (ƘƒƥơĂ!ƒ ǇDž ƥƧƞdž!ƒ) ƧŏƓżdž!ƒ ŎƛƒƥơŬƒ ýƛdžŏ ĂNjĂ Ü $x' = nd/L$ ǇƉ Ʀƺ
ƲơűŏƦƺ ÜDirichlet Ɨ!ƒƥƕ ƗƛdžƓƙdž!ƒ (5) Ɨ!ƥƓżdž!ƒ DžƥƤƘƪƙ ƗŏƖŏƖơ!ƒ ƧƓƬǉŮƒ Ɨ!ƒƥ ĬƼƵ ýĂƮơ!
:ƓdžƥǉƵ ƗƛƓdžƙdž!ƒ ĬdžƲż!ƒ ƱƓƖǉ!ƒ ƧnjƲƙĂ .(periodic) ĭƧĂƥ Ɨ!ƒƥ!ƒ ýƗƬ ǇƉ

$$2\pi\frac{d}{D}x' = q\pi \qquad q = 0, \pm1, \pm2, \ldots\ldots. \qquad \ldots\ldots\ldots\ldots\ldots(6)$$

Grating) lƨƨơdž!ƒ ƒ ĂŢ5!Gh Ĭdžʅŏ Gdž ƨĂnjƱ Ʊơǖlj Ȣ Ŧ!ƥƂ! ŦŏƨĂƥ!ƒ Ŧƒŏnj!ƒ (2) ýǂŢ!ƒ ƠưĂŏĂ ÜŦŏdžNjĂ ƻƒƥNjƉ ƥĂƞĂ ĬƂƵ lƨƓŢȘ ŎƱƶk GnjljǕ ýGhlkʅǕƒ Ŏ5 GNjƨĂnjƱ Ŏ5ǖk Ɣƞŏ ƒ ĂŢ5 ŎNjĂ (Lobes . ƒ ĂŢ5!ƒ ljȐNj ƨnjƱk Ǔ Ŧŏơh (yƖƱŢdž!ƒ) ƔǂƨĿ!ƒ ŎƒƒĂnj!ƒ DžŏdžŢk LJĂǂŏ LJƉ Ɣƞŏ ǁ!Ȑ!



.ƔȐȐƟDžǁƐ ƫ NjŢƻǁƐ ƞŢNjĭ lDžƨǁƐ LJƜƜƒG ĬƲɓdž ƹơNJǁ ƥƑʅƗǕƐ hǁƐq :(**2**) ülʅǁƐ

:ŦŏkǕƒ ŦljŏGhkdžƂ! (5) Ŧ!ƥǴdž!ƒ DžǴldž Ŏ5 ŦŏƨƱp ƻ Ţlj!ƒ ŦŏĂƒƨ!ƒ Ŧdžŏp ýưƤk LJƉ Ɣƞŏ Ȣ

$$2\pi \frac{d}{D}\frac{1}{2} \le \frac{\pi}{2} \qquad \Rightarrow \qquad \mathrm{d} \le \frac{\mathrm{D}}{2}$$

Ŧ5Ă5Ţdž ƨŢǴljƵ LJŏh ýŢƒĂ5!ƒ Ŧ5Ǵʅdž ƥŏƥơk Ɣƞŏ lƨƨơdž!ƒ ƒ ĂŢ5!ƒ LJdž ƒ ƂƤk!ƒ ýƞǕ (Pulse Ŧưhlj!ƒ ƨƒƨǂk ƥƥƨk Ŧdžŏp DžĂ LJdžĂ ŦƶŢdž!ƒ ƘǴưhlj!ƒ ƥƥƵ ĬƂƵ Ʃǂƶljŏ ƒȐNjĂ ƔǂƨĿ!ƒ ŎƒƒĂnj!ƒ ƥǴƞŏȘ ĬƂƵ ýdžƶ!ƒ Džkŏʅ5 Ŏkdžʅ!ƒ ljǴƞkǕƒ Ŏ5 Ŧpƥ!ƒ ĬƂƵ ýĂŢơƂ! GdžƉ .Repetition Frequency)PRF :[1]Ŏ!Ǵk!ƒ ýǂŢ!ƒ Ĭ!Ș (5) Ŧ!ƥǴdž!ƒ Ʊŏʅhk LJǂdžŏ Ŧŏơ Ü $x' = 0$ ƻ ƥnj!ƒ LJdž ŦhŏƨI!ƒ ƱǴlljƂ! Ŧpƥ!ƒ

$$f(x') = \sin c\left(\frac{2\pi L}{D}x'\right) \qquad ....(7)$$

. x LJdž lƨŏƺŢ DžŏI! ƥdžkƶdž!ƒ ($\sin(x) = x$) ƔŏƨIk!ƒ DžƒƥƤkʅGh ǁ!ȐĂ

:GNjƨƒƥldžĂ Ŏkdžʅ!ƒ ljǴƞkǕƒ Ŏ5 Ŧpƥ!ƒ LJƵ ƨhƶdž!ƒ ĂNj Ʃŏƒƨ!ƒ ƒ 5!ƒ Ŧdžƨơ ƱƨƵ LJƉ LJŏhkŏ (7) Ŧ!ƥǴdž!ƒ LJdž

$$\rho'_x = \frac{D}{2L} \qquad ....(8)$$

GnjƶưĂ Ĭ!Ș GnjƂŏĂơk!Ă ÜƘƒƥơĂ!ƒ LJdž Ŧŏ!ǴƤ ĭƉ lƨŏǴƶdž Ŧƺŏʅh Ŏkdžʅ!ƒ ljǴƞkǕƒ Ŏ5 Ŧpƥ!ƒ (8) Ŧ!ƥǴdž!ƒ ýƛdžk Ȣ :[1]Ŏkdžʅ!ƒ ljǴƞkǕƒ Ŏ5 Ŧpƥ!ƒ ƨƒƥldž LJĂǂŏʅĂ ÜL ýdžǴƶ!Gh Ɣƨưk (ýĂƱ lƥơĂ) ŎƂŢǕƒ

$$\rho_x = \frac{D}{2} \qquad ....(9)$$

ĬƂƵ ǕȘ ƥdžkƶk Ǖ GnjljƉ ƱơǖĂ Ŏkdžʅ!ƒ ljǴƞkǕƒ Ŏ5 GnjŏƂƵ ýĂŢơ!ƒ LJǂdžŏ Ŧpƥ ýư5Ɖ (9) Ŧ!ƥǴdž!ƒ ýƛdžk Ȣ GnjŏƂƵ ƾƂƱŏ Ŏk!ƒĂ ĭƨƒƥƒƨ!ƒ ƨŏĂŢk!ƒ ƘGdžĂƱljdž ƥlƵƒ Ŏ5 ǕȘ Ŧƥơk Ǖ Ŧpƥ!ƒ ljȐNjĂ ŎlŏlƠ!ƒ ŎƒƒĂnj!ƒ ýĂƱ NJŏƂƵ ýƥkʅŏ ƒȐNjĂ Ŧpƥ!ƒ ƘljʅƠk ŎƒƒĂnj!ƒ ýĂƱ Gljư5Ƥ GdžƂǂ NJLjƒ Gnjŏ5 Ʊơǖlj Ŏk!ƒĂ (focused) lƨhdž!ƒ

ƗƼĂƽ Ʈdž ƘƒƥơĂ ǇǀdžǏ ƧǇƗƒ ƥƥƵ ǋƙǉǈö DžǨ ǇǀdžǍĂ L Ɨdžöp ƥƒƥƨƙ D Ɨdžöp ǇǀƮ ǀǉǇ ǊǇƒ Ʀ (1) Ɨ!ƥǴƶdž!ƒ ǇǀdžǏ Ǵ ư ǑƊ
.ƴǉƱƮ dž!ƒ ǑƑƒĂǌ!ƒ

:ǉƯƾdž DžDž ǉƨ ǀƴǧƊǋǁ Ɣƥ ƑƮ Ǖ Ƹ ƥǊǋƯǊ ǭǭƥƗ ơǐƥƑƗǊ ƥƗǴǊǭ ƩƸƥƟdžƸ - 3

Doppler Variation with Phase and Frequency History of a Point Return:

Squinted) ƗƼƧơǇǀdž!ƒ Ɨöƶ ư Ă!Ǵǉ Ư ƧǕƒ ƴdž ƧƒƥƒƧ!ƒ Ɨdžƨơ Ɨƥǖƶ! ǑƮƥǉǌ!ƒ ǛƦĂdžǇ!ƒ ƦƤƊ Džǚ Ʈ ƗƼƧơǇǀdž!ƒ ƧöƩ ƗöƶưĂ!ƒ ǏǁƵ ƴĂƮơ!ƒ ǇƗdžö ǴǉǇdž Ǒƙ!ƒĂ DžƵǕƒĂ ƴdžƬǕƒ ƗöƶưĂ!ƒ ǴǉǇǕ Ǉ!ƦĂ (Mode Ɨdžƨơ ǉǴƞƙƒĂ ƴư Ă! ǑƮƥǉǌ!ƒ Ɣö Ɨ Ƨƙ!ƒ (3) ƴƗƬ!ƒ ǇǑǉö .ǇƗdždž ƧöƩ Σ Ɨƶ!ƒĂ (Unsquinted Mode) ƘǉǴǍ ƔǴƽƙƧǴǉ Ü x -ǑǍƒƥơǗƊ ǉǴƞƙǴǉ ƧöƮƙ ǉƧƑǴƱ!ƒ ǇƊ Ɨ öơ Ü Ư ƧǕƒ ǏǁƵ ƱǀƮdž!ƒ ƴƗƬĂ ƧƒƥƒƧ!ƒ ƗƶƬƊ ƴǍdžö t=0 Ǉdžƨ!ƒ Ɨ öơ Ü p ƗƱǀǇ!ƒ ƥǇƵ Ư ƧǕƒ ƠƱƮ ǏǁƵ ƴöǁơƙ!ƒ ǐ Ƨƞö Ʈ Ă .ƗöĂƙƮ dž Ư Ƨƒ ƾĂƼ (h_o) ƧƒƥƒƧ!ƒ Ǉdžǚ ăƥdž!Ǵƽ Ü(0,0,h_o) ƴƥĂdž!ƒ Ǒƽ ǐ Ɗ A ƗƱǀǇ!ƒ Ǒƽ ƧƒƥƒƧ!ƒ ǇĂƗö ǴdžƥǇƵĂ Ü ƗǉƥƒƧdž!ƒ ǉƧƙƽ ƨƗƧdž
:[4]ĂǊ p ƗƱǀǇ!ƒ ǏǇ!ǫ

$$r_o = \left(x_o^2 + y_o^2 + h_o^2\right)^{\frac{1}{2}} \qquad ....(10)$$

:ƗöƙǙƒ Ɨƥǖƶ!ƒ Ǉdžǚ ƔƮơƙ Ǒƙ!ƒĂ ϕ ǑǊ p ƗƱǀǇ!ƒ ǏǇ!ǫ ăƥdž!ƒ ǋƞƙdžĂ ǉƧƑǴƱ!ƒ ƗƵƧƮ ǋƞƙdž ǇǑǉ ƗöĂƒƨ!ƒ

$$cos\,\phi = \frac{x_o}{r_o} \qquad ....(11)$$

ƻǴƱƶǇǫ ƗöĂƒƨ DžƮƒ ƗöĂƒƨ!ƒ ǉƦǊ ǏǁƵ ƾǁƱöĂ ǕǑǀöǀơ!ƒ ǑƑƒĂǌ!ƒ Ɨdžƨơ! ƗöǊǴƞƙƒ ƗöĂƒƨ ǑǊ : ϕ Ʀ ƴƗƬ!Ǵǉ δ Ă ϕ ǇǑƙöĂƒƨ!ƒ ǇǑǉ ƗöƮƥǉǌ!ƒ Ɨƥǖƶ!ƒ ƻöƧƶƙ ǇƗdžöĂ . (radar cant angle) ƧƒƥƒƧ!ƒ :[5]ǑƙǙƒ

$$cos\,\phi = cos\,\delta\, cos\,\psi$$

Squint) ƻƒƧơǇǙƒ ƗöĂƒƨ DžƮǫ ǴǉöǁƵ ƾǁƱöĂ Ü Ư ƧǕƒ ƠƱƮ ǏǁƵ ϕ ƗöĂƒƨ!ƒ ƱǀƮdž ǑǊ : ψ Ʀ .(Angle

ǉƥƙƧdž!ƒ ǉƧǴƬǙƒ ƘǴǇǴǉ ƴdžƞ Ǌ!ǖƤ Džǚö ǐƦ!ƒĂ ǉƧƑǴƱ!ƒ ƧǴƮdž Ǉdžǚ ƴƱǀdž ĂǊ (L) ƗǉƥƒƧdž!ƒ ƴƱǀdž ÜL ƴƱǀdž!ƒ ƴĂƱ ǏǁƵ ǑǀöǀơǑƑƒĂǌ!ƒ ƔǴƶƬǫ Ɨdžƨơ Ǉdž ư p ƗƱǀǇ!ƒ ǇĂƗƙ ǇƊ ƔǁƱƙö ƒƦǊĂ Üp ƗƱǀǇ!ƒ Ǉdž ǏƱƶǊ (Coherent Integration Time) ƱǉƒƧƙdž!ƒ ƴödžƞƙ!ƒ Ǉdžƨ ǋöǁƵ ƾǁƱö ƥp ĂƊ Ta ƗǉƥƒƧdž!ƒ Ǉdžƨ :Ɨƥǖƶ!Ǵǉ

$$T_a = \frac{L}{v} \qquad ....(12)$$

:[4]ǇĂƗƙƮ ăƥdž!ƒ Ɨ!ƥǴƶdž ǇƼ Ta ƗǉƥƒƧdž!ƒ Ǉdžƨ ƴǖƤĂ .ǉƧƑǴƱǁ! ƗƙǴǍ!ƒ ƗƵƧƮ!ƒ ǑǊ v Ʀ

$$r(t) = \left[y^2 + (x_o - vt)^2 + h^2\right]^{\frac{1}{2}} \qquad -T_a/2 \le t \le T_a/2 \qquad ....(13)$$

:[4-7]ǋƙǴǇ!ƒ ǇĂƗöƮ ƸƽǴƗdž ƴƱp Ǐ!ǫ ƥƑƒƨ ƴƱp Ǉdžǚ ǴǉǁöĂơƙǉ (13) Ɨ!ƥǴƶdž!ƒ ƱöƮǉƙ ƥƶǉĂ

$$r(t) = r_o - vt\,cos\,\phi + \frac{v^2 t^2}{2r_o} sin^2\,\phi \qquad ....(14)$$

:ŧpǖz!ƒ ŧƠʅƒĂƕ ƨƕĂþ ŧơƒɐ þþƨk Ĭ Ƶ ýĂʈơ!ƒ LJŧdžŏĂ

$$f_d = \frac{2}{\lambda}\frac{\partial r(t)}{\partial t} \qquad ....(15)$$

:[4]Njkljŏ (15) ŧ!þǴzdž!ƒ Ĭ5 (14) ŧ!þǴzdž!ƒ Ưŏ Ăzkƕ Ă

$$f_d = \frac{2v}{\lambda}\cos\phi - \frac{2v^2 t}{\lambda r_o}\sin^2\phi \qquad -\frac{T_a}{2} \le t \le \frac{T_a}{2} \qquad ....(16)$$

Üăþdž!ƒ Σ5lj Ĭ Ƶ ĭ D (3) ýŧT!ƒ Ŏ5 (A) ŧƠlļ!ƒ LJdž NJʅ5lj þzƕ!ƒ Ĭ Ƶ LJǴzlŏ LJŏ5þNj þĂɳĂ þljƵ LJdžɐ!ƒ LJƵ ƨƕzŏ p ýĂŰƒ ƻþnj!ƒ LJD Ưƒƨk5ƕ Ü ρ_x ǴNjƨƒþldž ŧ5ǴʅdžƕKdžʅ!ƒ ljǴɳkƒ Ŏ5 LJǖʈ5ljdž Ǵdžnjljŧ!Ă Üăþdž!ƒ Σ5ljƕ ǴnjljD Ʀ p ŧƠlļ!ƒ LJdžɐ Ĭ!ǫ ŧƕʅlj $t=\rho_x/v$ LJdžɐ!ƒ LJƵ ƨƕzŏʅ p' ŎljǴλ!ƒ ƻþnj!ƒ LJǴ5 t=0 ÜǗưŏD ŧ5ƨơljdž LJĂŧk ƻĂʅ LJŏkƠlļ!ƒ LJdž ŧɳkǴlj!ƒ lƨĂʈ!ƒ LJǴ5 f pǴlj!ƒ yƠl!ƒ Ŏ5 ƻƒƨơljǕƒ ƔƕʅƕLJŧ!Ă yưĂdž ýŏþzk Ɣɳŏ NJljǴ5 (Strip Mode) ŎƠŏƨT!ƒ ƔĂʅǕǴƕLJĂŧk LJD Ɣɳŏ ŧƕĂƠdž!ƒ lƨĂʈ!ƒ LJD ǴdžƕĂ p'' ŧƠlļ!ƒ LJǴ5 ǁ!Ʀ! ÜǗŏƠŏƨT lƨĂʈ!ƒ ýŧT LJĂŧŏ! (3) ýŧT!ƒ Ŏ5 ŧơưĂdž!ƒ p'' Ĭ!ǫ p' ŧƠlļ!ƒ LJŏƕ ƨƕĂþ ŧơƒɐ þþƨk Ŏ5 ƽƨ5!ƒ LJǴ5 DžĂ LJdžĂ Üp ŧƠlļ!ƒ Ĭ!ǫ ŧƕʅlj $t=\frac{\rho_x\,sin\psi}{v\,sin^2\phi}$ LJdžɐ!ƒ LJƵ ƨƕzkʅ :LJĂŧŏʅ p'' Ă p' LJŏkƠlļ!ƒ

$$\Delta f_d = f_d\big|_{t=0} - f_d\big|_{t=\frac{\rho_x\,sin\psi}{v\,sin^2\phi}} \qquad ....(17)$$

:[5]Njkljŏʅ (16) ŧ!þǴzdž!ƒ Ŏ5 Ưŏ Ăzk!ƒ þzƕĂ

$$\Delta f_d = \frac{2v}{\lambda r_o}\rho_x\,sin\psi \qquad ....(18)$$

LJŏƕ ɐŏŏdžk!ƒ ĂD ýʈ5!ƒ Ĭ Ƶ ƠTƨdž!ƒ ŧŏƕǴp LJǫ ÜƨƕĂþ ŧơƒɐ ŧdžɐơ ƯƨƵ LJƵ (18) ŧ!þǴzdž!ƒ ƨƕzk ŧɳ!Ǵzdž ǴljNj DžkŏĂ ÜǴnjkɳ!ǴzdžĂ lƨǴTŰƒ yŏdžɳk! ŧŏljdžɐ!ƒ lƨk5!ƒ ydž ǗŏʅŧƵ ƔʅǴljkk Δf_d ljƨƒþldž ƽƨǴ5ƕ LJŏþþƨk ŧdžɐơ ƯƨƵ LJǴ5 DžĂ LJdžĂ ÜTa ĂNj Ǵnjkɳ!Ǵzdž! ƘǴưƕlj!ƒ ljƦNj yŏdžɳk LJdžɐ LJĂŧŏʅ Ʀ ƘǴưƕlj!ƒ LJdž ŧ ʅ ʅ :[4]LJĂŧŏʅ ƠTƨdž!ƒ

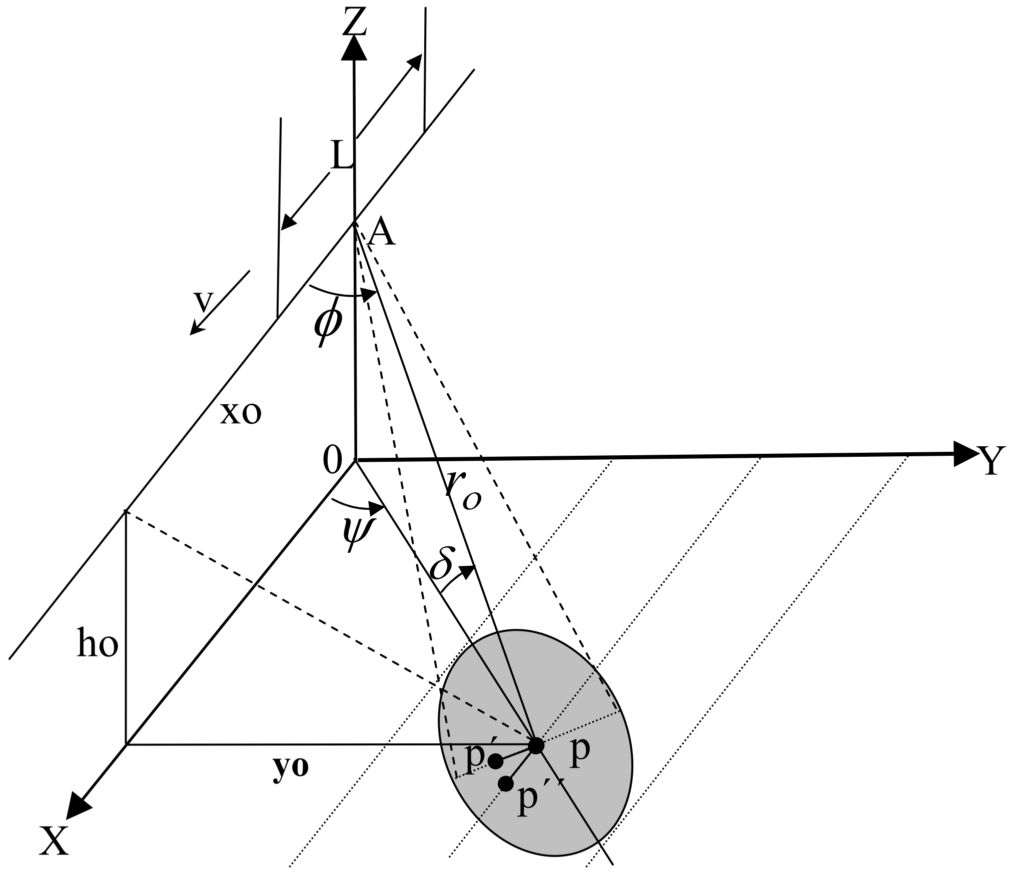
$$\Delta f_d = \frac{1}{T_a} = \frac{v}{L} \qquad ....(19)$$

:[5]Njkljŏʅ (18) ŧ!þǴzdž!ƒ ydž (19) ŧ!þǴzdž!ƒ lƒĂǴʅdžƕĂ

$$\rho_x = \frac{\lambda r_o}{2L} csc\,\psi \qquad ....(20)$$

NJkdžŏlƕ L Ɣŧƨdž!ƒ ŎƒƒĂnj!ƒ ýĂƠ ƦPƒ Džkŏʅ Ŏkdžʅ!ƒ ljǴɳkǕƒ Ŏ5 ŧpþ! ŧŏƑǴnjlj!ƒ ŧʒŏʈ!ƒ Ĭ Ƶ ýĂʈơ!Ă DžĂ LJdžĂ ŧdžŏp Ĭ Ƶƕ Ta ƘǴưƕlj! ŧƠƕƒƨkdž!ƒ ŧɳ!Ǵzdž!ƒ LJdžɐ ƦPƒ Ɣɳŏ NJljƒ Ĭ!ǫ ĭþƋŏʅ ƒƦNjĂ ĬdžǙz!ƒ :ƠTƨdž!ƒ ŧdžɐơ ƯƨƵ LJĂŧŏʅ

$$\Delta f_d = \frac{1}{T_{a\,max}} = \frac{v}{L_{max}} \qquad ....(21)$$



.hyÿďŬƬĎŽǁ hɵŧƻǁ ƥɛǫƐƥǁ Ƹ ƥɵďďŽǁ Ǐ ƨǫďŊǁ ƱƮŊǁ :(3) ü|ʅǁ

:[5-7]LJĂŧƙʅ Ʀǫ $T_{a\,max}$ Ŧďžǒp LJD ǅǒʅƥǈǋ ɰƓƙǉƙʅǕƒ LJŧďǒ (3) ýŧT!ƒ LJďžĂ

$$T_{a\,max} = \frac{r_o \phi_a}{v \gamma_g} \qquad ....(22)$$

ĎžƒƥƤƙʅƒ ƥǉƵ ƧǌƱǒ ǐŖ!ƒ Ǒʅƥǉǌ!ƒ ýďžƓƶ!ƒ ǑŊǰĂ $\gamma_g = \left(\sin^2\psi + \cos^2\psi \sin^2\delta\right)^{1/2}$ LJD Ʀǫ

(21) Ŧ!ƥƓƶďž!Ɠƕ (18) Ŧ!ƥƓƶďž!ƒ ǀƒĂƓʅďžƕĂ . $\phi_a = \frac{\lambda}{D}$ ÜŦ5ƧƠǉďž ŦǒƶƜĂƕĂ ($T_{a\,max}$) ŦƕƒƧďž LJďžƨ ĎžƱƵD

:[5]Ŋƙǉǒ

$$\rho_x = \frac{D}{2}\sqrt{1 + \cot^2\psi \sin^2\delta} \qquad ....(23)$$

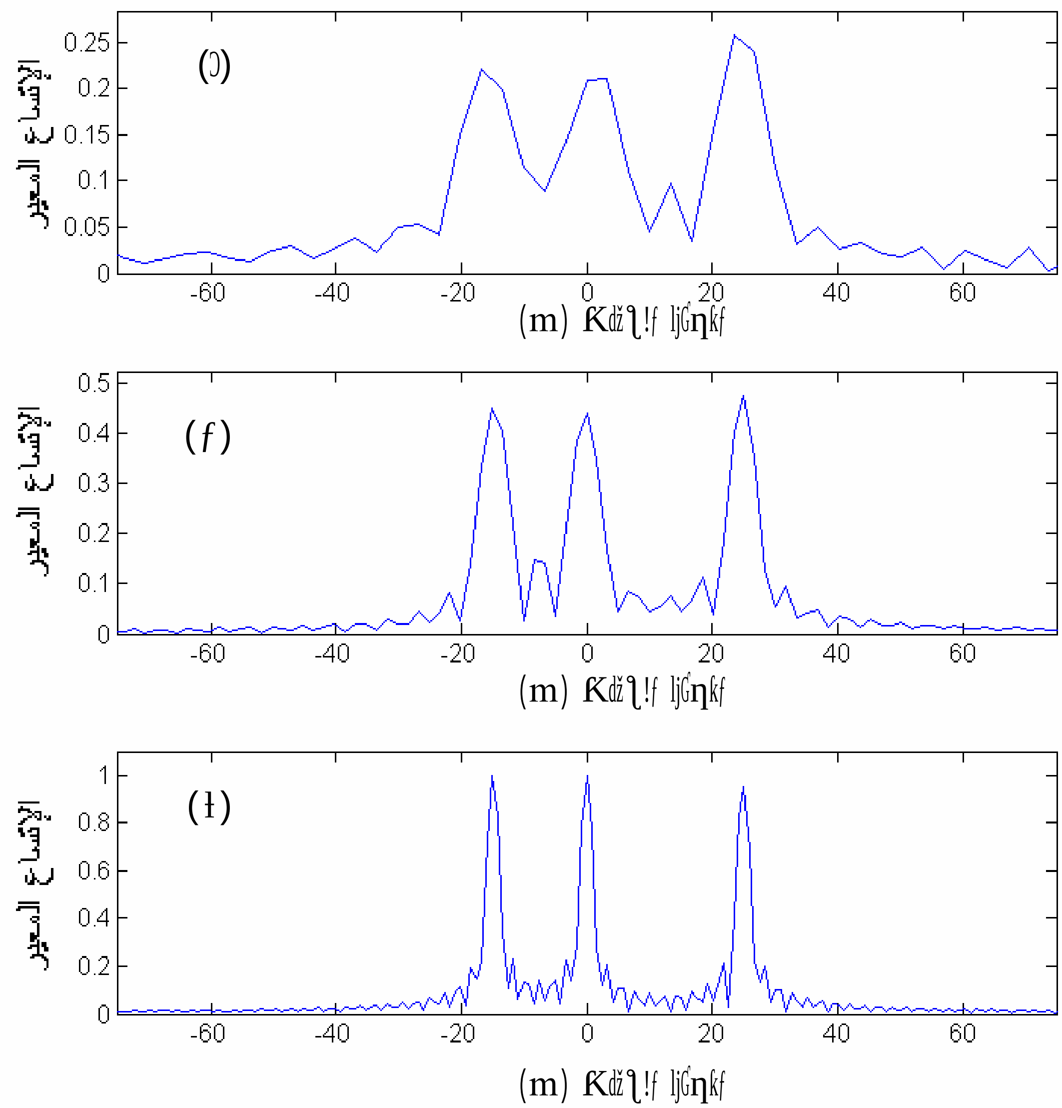
4- [illegible]

Performance evaluation for the focused SAR system under various operating conditions:

[illegible] Matlab) [illegible] (Toolbox_VER.6.5 [illegible] .[9] [illegible] (Sample) [illegible] (FFT) [illegible] (IFFT) [illegible]

4.1- [illegible]

[illegible] $(T_a=1s)$ [illegible] $(r=60km)$ [illegible] $(\lambda = 0.033m)$ [illegible] $(h=20km)$ [illegible] $(\psi = 48^o)$ [illegible] (4) [illegible] [11-15] $(v = 100\ ,200\ ,400\ m/s)$ [illegible] (Normalized Amplitude) [illegible] (T_a) [illegible] (L) [illegible] (22) [illegible] (L_{max}) [illegible] (L) [illegible] (23) [illegible] (20) [illegible] (23) [illegible] (L_{max}) [illegible] (L) [illegible] (Focusing) [illegible]



ǫďY ǐĎƨǁ ǇƑɯƜƑĜ ƒ ƥǕƐ ǍƚY ƕYǸƮǸǰ ƕǏƲƨď ƸƐǫǈƈ ƕƙǘƙ ĎďĎ ƕƴɯƥƚƨĎǁ Ɣƥǹƭǁ:(4) üǀ٦ǁ
:Ʊƥƨ Ƙǘƙǀ ǏƚĎƨǁ ǇƑɯƚǗƐ Ǐƺ ƕƨǫǁǁ ĎƮǴƚ Û(-15 ǹ 0 ǹ 25) ǕƑsďǁ

$v = 400m/s$ - ł $v = 200m/s$ - f $v = 100m/s$ - ﺃ

Ƙǘƙǀ ƔƑǀƑƟĎǁ ƛĎƑďƥĜ ĎďĎǸ (20) ƕǁǫƑƴĎǁ ĎďĎ ƕĜǸƨƟĎǁ ǏƚĎƨǁ ǇƑɯƚǗƐ Ǐƺ ƕƨǫǁǁ ƛƏƑƚď :(1) üǸǫɯǁ
.ƕYƥƨƚǁ !ǏƨS

	ρ_x (m) ǑƙďٳǁǉĜɳƙǗƒ Ǒƽ ƚƥƥ!ƒ		
$v\,(m/s)$ ƚƵƨ٦!ƒ	ƚ!ƥĜƺďǃƒ Ǉďǐ	ǸďĜǇƨƕ!ƒ Ǉďǐ	% ďƱP!ƒ ƚƕ٦ǉ
čČČ	13.4	13.5	0.75 %
ĎČČ	6.7	7.3	8.95 %
ĐČČ	3.35	3.7	10.44 %

[illegible] ($v = 100m/s$) [illegible] (L=200m) [illegible] ($v = 200m/s$) [illegible] (L=100m) [illegible] .(L_{max}=624m) [illegible] (22) [illegible] (L=400m) [illegible] ($v = 400m/s$) [illegible] (20) [illegible] .(1) [illegible]

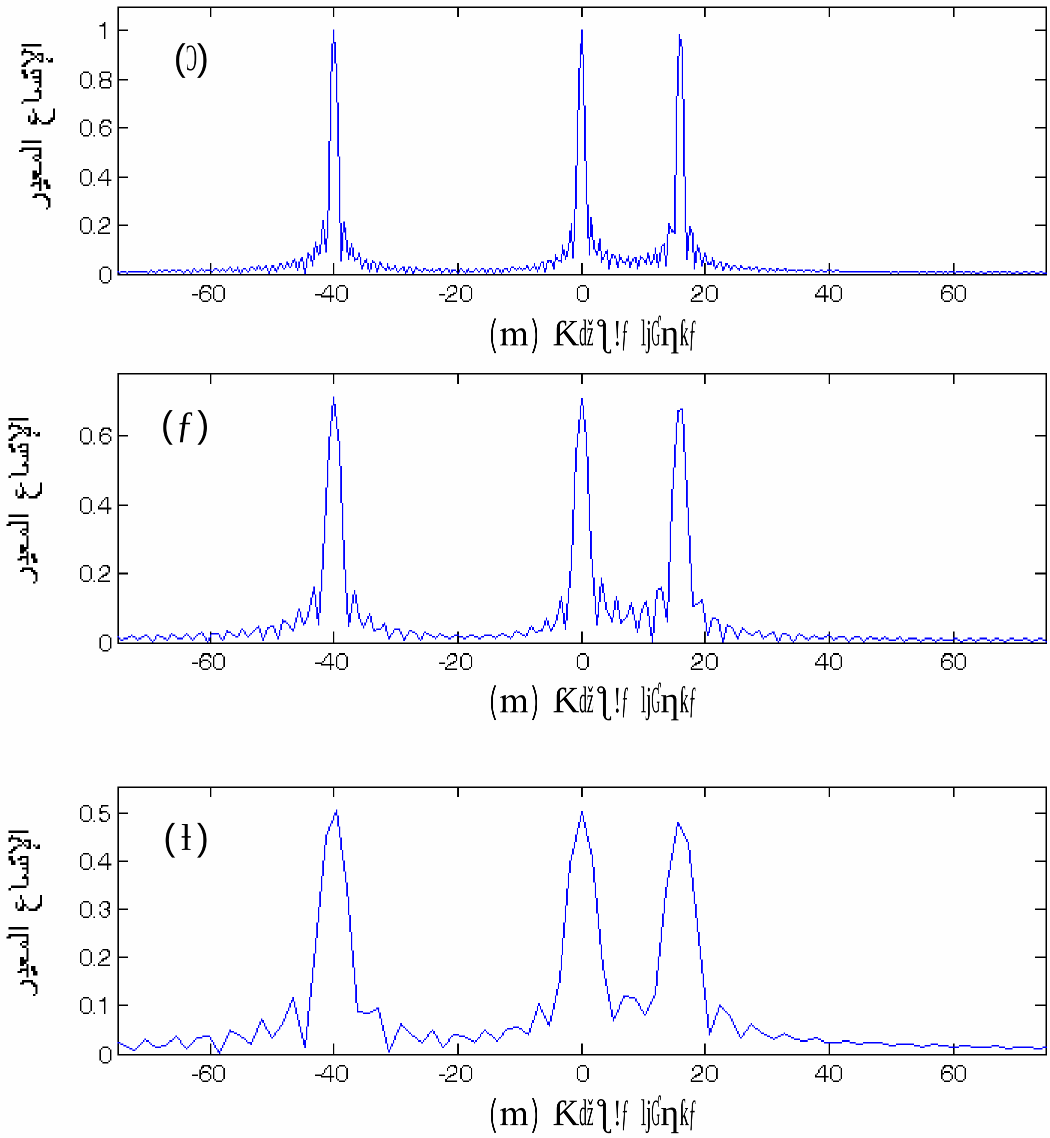
[illegible] (1) [illegible] (20) [illegible] .(4) [illegible] Rayleigh [illegible] 0.8 [illegible] [9,10] [illegible]

[illegible] -4.2

[illegible] ($\lambda = 0.033m$) [illegible] ($\psi = 46^o$) [illegible] ($v = 220m/s$) [illegible] (T_a=1s) [illegible] (r=15.8km) [illegible] (h=3km) [illegible] (h=25km) [illegible] (r=31km) [illegible] (h=10km) [illegible] (ɖ) [illegible] .[11-15] (r=65.4km) [illegible] (20) [illegible] (20) [illegible] (5) [illegible] .(L) [illegible] (2) [illegible] .(2) [illegible]

[illegible] -4.3

[illegible] ($v = 100m/s, h = 3km$) [illegible] ($v = 200m/s, h = 10km$) [illegible] (r=14.5km) [illegible] .(r=106km) [illegible] ($v = 400m/s, h = 25km$) [illegible] (r=44km) [illegible] ($\psi = 51^o$) [illegible] ($\lambda = 0.033m$) [illegible] .[11-15] (D=4.5m) [illegible] (T_a=1s) [illegible] .(6) [illegible] (20) [illegible] .(3) [illegible] lƧĂǂƦdž!f ƔƖǉ!Ǵh) ǿzdž ǂƩƧƖ!fĂ YǴ5kƧŬf Ŏkdžöp Ư ö5Ƥk ǂ!Ǵơ Ŏ5 NǉD (3) ýĂþƞ!f LJdž LJöhkö ǂpþ!f ƧĂNjþk Ĭ!ǫ ĭþƋö ǂƩƧƖ!f ǂdžöp Ư ö5Ƥk LJD LJdž DžƸƧ!f ĬǁƵ ŬŎkdžƖ!f ǉǴƞkŬf Ŏ5 ǂpþ!f ƘǉƖơk (ǉŭƵD ƧöǅdžkLJǴǂ ŬǴǉNj ǴNjƧǴökƤf Džk Ŏk!f ǂƩƧƖ!fĂ YǴ5kƧŬf Džöl! NǉD Ăþhö LJǂ!Ă .(4) ýǂT!f Ŏ5 LJöhdž ĂNj Ǵdžǂ NǂdžČĂƖk ĭƦ!f) ǂƩƧƖ!f ƯǴ5ƤǉfƧöǅdžk LJdž Ƨhǂf (ǂpþ!f LJƖơk Ĭ!ǫ ĭþƋö ĭƦ!f) YǴ5kƧŬf ƯǴ5Ƥǉf .Ŏkdž Ɩ!f ǉǴƞkŬf Ŏ5 ǂpþ!f LJƖơk ŎNj ǂǁƬơdž!f ƘǉǴǂ fƦǂNjĂ .(ǂpþ!f

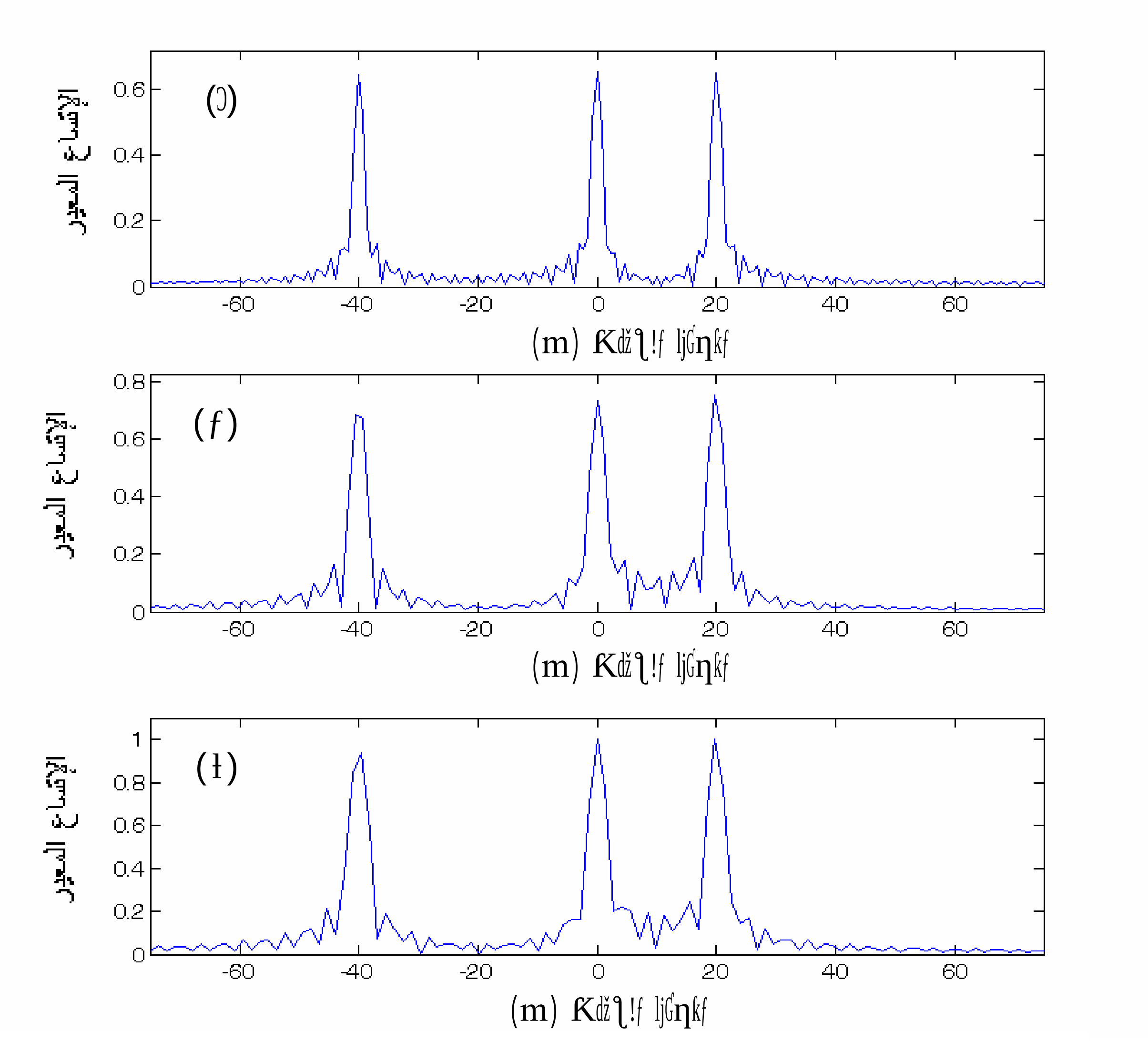


ǫdžY lDžƨǁǁ LJFШǂFǴ f þŬƐ ĂǂY hYNjƬNjDž hĭƯsdž ƸƐǫljc hkǘk DžDž hyШþǂƨDžǁǁ YþNjƬǁǁ : (5) üǉƖǁǁ
:ĬǁNj5FƖǁǁ ƢF2ǂþŬƐ DžDž !ĭ5 Ƙǘkǁ ĬǂDžƨǁǁ LJFШǂŬƐ Ĭƺ h5ǫǁǁ DžĭǴǂ Û(-40 Nj ċ Nj 15) ƯFsdžǁǁ

$h = 25km$ - ǂ $h = 10km$ - f $h = 3km$ - Ɔ

ƘǘƙǁƔ ƔƑǀƑƟƊǎǁƐ ƛƊǎƑǗƥƓ Ɗǎƍǎǆ (**20**) ƵǁǀƑƔƊǁƐ Ɗǎƍ ƵƓǆƾƟƊǁƐ ƏǂƊƾǁƐ ǈƑǄǂǛƐ Əƺ ƵƼǀǁƐ ƛƥƑǂǎ :(**2**) ǜǆǀǄǁƐ
. ƏǁǆƼƑƸǁƐ ƷƑƼƥǘǁ !ǃƼ

	ρ_x (m) ǑǆǎƸ!ƒ ǉǴƞǀǓƒ ǑƼ ǂƥ!ƒ		
h(km) Ǒ!ǍƥǴT!ƒ ƳǴƼǀƧǓƒ	ǂ!ƥǴƶǎ!ƒ ǇǄǎ	ǋǎǴǈƧǁ!ƒ ǇǄǎ	% ǆƷƤ!ƒ ǂǁƸǉ
3	1.7	1.9	11.76 %
10	3.3	3.4	3.03 %
25	6.9	7	1.45 %



ǓƑƼǁƐ ǀǎƳ ǃƊƾǁƐ ǈƑǄǂǴ ƒ ƥǗƐ ǍƤƳ ƵƳǆƬǆǎ ƵǏǓƼǎ ƹƐǀǆǴ ƵǘǎƘ Ɗǎƍ ƵƔǀƥƾƊǁƐ ƔƥǆƬǁƐ:(ƌ) ǜǃƸǁƐ
: ƏǁǆƼƑƸǁƐ ƷƑƼƥǗƐǆ ƵƔƥƾǁƐ Ɗǎƍ ǃǗƑƟ ƘǘƙǁƐ ƏǂƊƾǁƐ ǈƑǄǂǛƐ Əƺ ƵƼǀǁƐ ƊǎǴǂ Ǜ(**-40** ǆ **0** ǆ **20**) ƵǏǂƟǛƐ

$v = 400m / s, h = 25km$ - ǂ $v = 200m / s, h = 10km$ - ƒ $v = 100m / s, h = 3km$ - Ɔ [illegible] (20) [illegible] :(3) [illegible]

[illegible] h(km)	$v(m/s)$ [illegible]	ρ_x (m) [illegible]		[illegible] %
		[illegible]	[illegible]	
3	100	3	3.1	3.33 %
10	200	4.6	4.7	2.17 %
25	400	5.6	5.7	1.78 %

4.4- [illegible]:

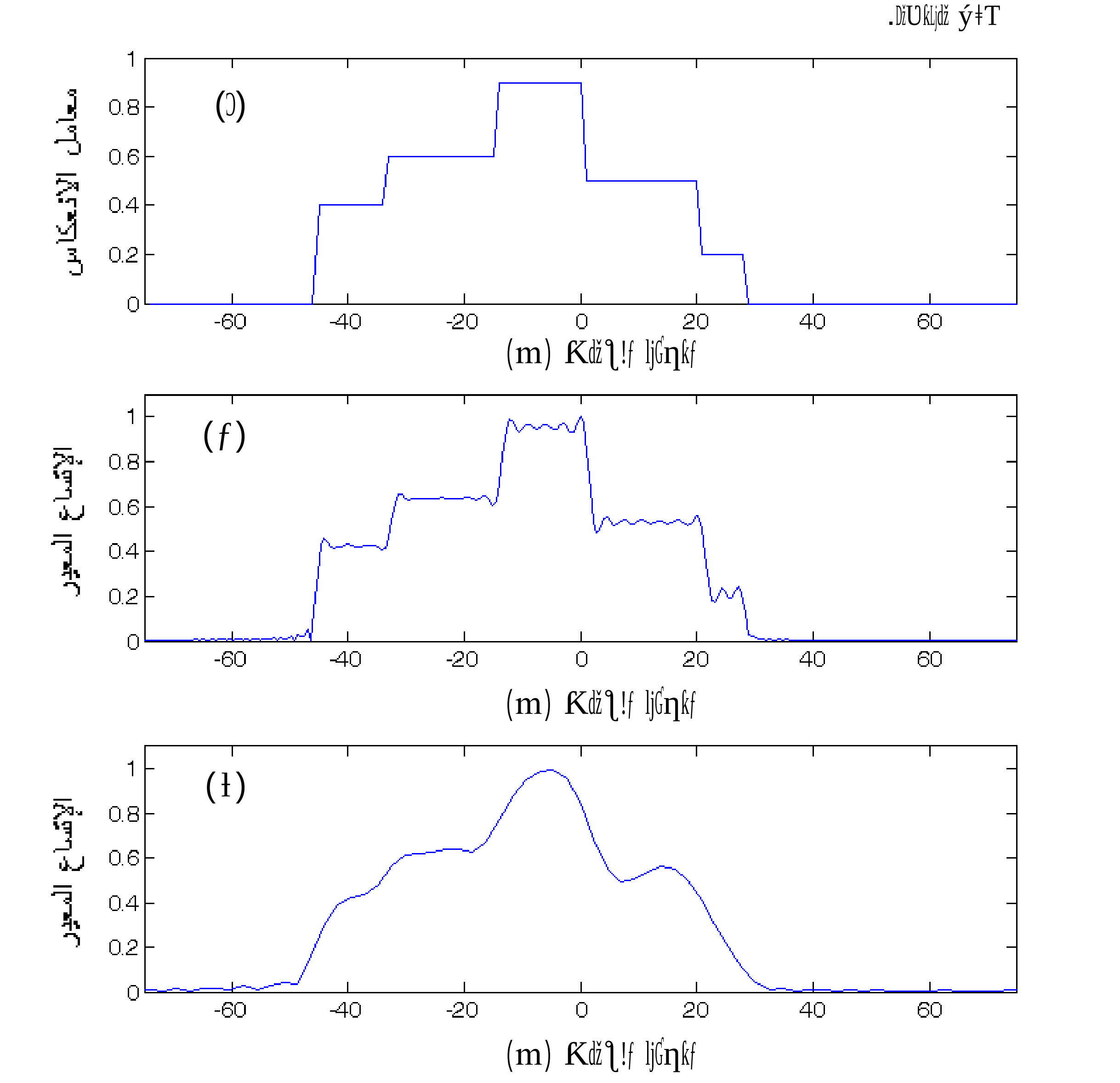
[illegible] (Continuous) [illegible] (7ج) [illegible] (L) [illegible] (7ب) [illegible] ($v = 400m/s, h = 10km$) [illegible] (7ب) [illegible] ($\rho_x = 2.4m$) [illegible] $30 \approx 74/2.4$ [illegible] ($\rho_x = 10m$) [illegible] ($v = 100m/s, h = 10km$) [illegible] (7أ) [illegible] $7 \approx 74/10$ [illegible].

Conclusions: [illegible] -5

1- [illegible] (L) [illegible] (Ta) [illegible] (L) [illegible] (Ta) [illegible].

2- [illegible] ((4.4) [illegible]).

3- [illegible] ... Rayleigh [illegible] ... 0.8 [illegible]



[illegible] (7) [illegible] (-45 [illegible] 28) [illegible]:

[illegible] -

[illegible] $\rho_x = 2.4m$ [illegible] -

[illegible] $\rho_x = 10m$ [illegible] -

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