21 September 2009

ERRATA[1]

for the 1st and 2nd printings of the textbook:
"Doppler Radar and Weather Observations", Second Edition-1993
Richard J. Doviak and Dusan S. Zrnic'
Academic Press, Inc., San Diego, CA. 562 pp.
ISBN 0_12_221422_6.

Reprints of this textbook are available from
Dover Publications, Inc, www.doverpublications.com[2]

Page	Para.	Line	Remarks: Paragraph 0 is any paragraph started on a previous page that carries over to the current page. A sequence of dots is used to indicate a logical continuation to existing words in the textbook (e.g., see errata on pp. 14, 76, paragraph 3, on p. 108, etc.)
xvii	1	1	Dover edition, rewrite as "…identical to the 1st and 2nd printings.."
xvii			add to list of symbols: g_s System gain
			in list of symbols change: c Speed of light in a vacuum
			add to list of symbols: γ Mass density of air
			delete from list of symbols: ρ Mass density of air
10	Eq.(2.2a)		Change ψ to ψ_t
11	0	1	as above
	2	2	as above
	Eq.(2.2b)		as above
12	Fig.2.3		as above

---

[1] The authors thank Dr. R. E. Rinehart, University of North Dakota, for many of these entries.

[2] The Dover Edition is currently in print and, except for an additional preface, is identical to the 1st and 2nd printings (not the 3rd and 4th printings as stated in the preface to the Dover edition). Errata for these printings are posted on NSSL's website at nssl.noaa.gov; click the links to Publications, Recent Books, and Errata.

Academic Press had also released a 3rd and 4th printings, in which some errors in the earlier printings were corrected. The errata for these later printings are also presented on the website and these errata are updated periodically. Because the errata for the 1st and 2nd printings are not updated, readers of these earlier Academic printings and of the Dover reprint might need to refer to both sets of errata to find all corrections.

Also listed in the errata are Supplements that clarify or extend the book text.

14	2	1	change to read: "…on the change of the refractive index, $n = c/v$, with height (or, because the relative permeability μ_r of air is unity, on the change of relative permittivity, $\varepsilon_r = \varepsilon / \varepsilon_0 = n^2$, with height).
		4	"contet" should be "content"
		7	change period to comma after "content"
		8	insert "are" to read "developed herein are useful"
15	1		change ρ to γ in line 14, in Eqs.(2.8) and 2.9, and line 19
18	Fig.2.5		change caption to: "...in which n decreases with height."
30	2	9	italicize the "o" in oscillator
		10	change "ad" to "and"
	3	7	delete the parenthetical phrase
31	Fig.3.1		Change "synchronous detector" to "synchronous detectors"
32	5	4	Insert the sentence: "The region beyond $r = 2D_a^2/\lambda$ is called the far field; there the power density has an angular dependence independent of range, and an inverse r^2 dependence."
33	1	3	change "reflector" to "reflector's aperture"
34	Eqs.3.2		replace D with D_a
35	1	3	delete period at end of line
	1	9	insert the word "transmitting" before antenna; at the end of the last sentence add: with origin at the scatterer.
	2	10	the equation on this line should read: $\sigma_b = \sigma_{bm}\left(1 - \sin^2 \psi / \sin^2 \theta\right)^2 \cos^4[(\pi/2)\cos\theta] / \sin^4 \theta$
	Eq.(3.6)		change K_m to K_w in this equation and in the line following it
36	0	7	change to $\lvert K_m \rvert^2$ to $\lvert K_w \rvert^2$

		9	change the end of this line to read: "Ice water has a $\lvert K_i \rvert^2$…"
38	2	3	change "λ = 3 cm" to "λ # 3 cm"
39	1	4, 5	use the symbol for *l* in Eq. 3.13b as in 3.13a
40	Eqs. (3.14a, b)		replace subscript "m" with "w"
42	Fig. 3.5		insert *Z* in front of (dBZ) in the abscissa label
43	1	1	Replace "Remove" with "Remote"
	3	6	change to "...attenuation for liquid cloud is..."
	Eq.(3.17)		change subscript "m" to "w"
44	0	2	"0.9 dB" should be "0.43 dB"
45	Fig.3.6		ϕ_e should be θ_e
47	Table 3.1		change title to read: "The *nex*t generation *rad*ar, NEXRAD (WSR-88D), Specifications" change "Beam width" to "Beamwidth" change footnote *b* to read: "Initially the first several radars transmitted circularly polarized waves, but now all transmit linearly polarized waves". change footnote *c* to read: "....antenna port, and a 3 dB filter bandwidth of 0.63 MHZ is assumed.
50	1	8	remove comma
	Eq.(3.25)		change ψ to ψ_t
51	1	11	delete sentence beginning with "Thus the sign..."
	Eq.(3.27)		Delete "sin(ωt)"
52	1	9	Start a new paragraph at: "A physical explanation...
		13	Change "the scatter" to "its"
60	4	11	change "directly" to "correctly"
61	0	7	Delete "(or folding)"

		14	last line change to “velocity limits (Chapter 7).”
	Fig.3.14		change $\gamma(t)$ to $\psi_e(t)$ and $\Delta\gamma$ to $\Delta\psi_e$
	Eq. (3.40b)		place ± before v_a
64	3	2	"than", not "then"
65	0	6	remove comma after "size"
	1	4	change to: ....pulses (I and Q) at the output.....
	Fig.4.2		replace W with I in the figure, and change caption to read:...output I (or Q) to....and r_o is the range where scatterers contribute maximum weight to the sample gate at τ_{s1} (Section 4.2.2).
66	0	2	change $V(t) = I(t)+jQ(t)$ to $V(\tau_{s1}) = I(\tau_{s1}) + jQ(\tau_{s1})$.
67	3	1	Insert after $V(\tau_s)$: "at the receiver's output"
68	1	7	bracketed text should end "...in Eq. (4.2).]", i.e., put period between right parenthesis and bracket
	3	8	change to read as: “or expected power $E[P(\tau_s)]$.”
68-69	4	1,10,12	change “$\overline{P}(\tau_s)$” on these three lines to “$E[P(\tau_s)]$”
71	Eqs.(4.4a,b)		insert $(1/\sqrt{2})$ in front of the sum sign in each of these equations
	3	6	replace “p. 418" with “p. 498"
	Eq.(4.6)		Delete the first “2"
72	0	4	change $\overline{P}(\tau_s)$ to $E[P(\tau_s)]$
	2	1	change $\overline{P}(\tau_s)$ to $E[P(\tau_s)]$
		3	remove footnote
73	Eq. (4.11)		change “$\overline{P}(\boldsymbol{r}_0)$” to “$E[P(\boldsymbol{r}_0)]$”.
74	Eq.(4.12)		delete the boldness of "**r**"
	4	1	measurem(m)ents; delete the extra "m"

74-75	Eqs. (4.12), (4.14), (4.16):		change “ $\overline{P}(\boldsymbol{r}_0)$ ” to “$E[P(\boldsymbol{r}_0)]$”.
75	1	6	change to "$G(0) \geq 1$"
	2	18	change “ $\overline{P}(\boldsymbol{r}_0)$ ” to “$E[P(\boldsymbol{r}_0)]$”.
76	0	5	change "output of" to "input to"
	1	5	envelop<u>e</u>
		7	change to read:....the output of the receiver would be that sketched in Fig.3.12.).
Fig.4.5			change second sentence in caption to read: “The broad arrow indicates sliding of....”
82	Eq. (4.34)		change “ $P(\bar{\boldsymbol{r}}_0)$ ” to “$E[P(\boldsymbol{r}_0)]$”.
	Eq. (4.35)		change “ $\overline{P}(\text{mw})$ ” to “$E[P(\text{mw})]$
	1	9	should read: “... is the *reflectivity factor* of spheres.”
		17	change to read: “10 $\log_{10} Z$, where Z is in units of mm^6/m^3 and the scale of $Z(\text{dBZ}) \equiv 10 \log_{10} Z$ is in dBZ units.”[3]
83	Eq.(4.38)		subscript "r" should be "τ"
	3	14-16	change to read "...375 kHz. For a radar transmitting a rectangular pulse and using a matched Gaussian filter (i.e., $B_6\tau=1$), one finds..."
84	Eq. (4.39)		change “ $\overline{P}(\boldsymbol{r}_0)$ ” to “$E[P(\boldsymbol{r}_0)]$”.
85	Fig.4.10		the ordinate should have the label "Correlation coefficient $R_{vv}/R_{vv}(0)$"
	Problem 4.1		change “ $\overline{P}$ ” to “$E[P]$” in two places.
94	4	5	change to "Noise-like signals..."
101	3	2,3,5	add comma after "domain" and one after "(Fig. 5.10 RECT)"

---

[3] For discussion of the dBZ “unit”, see the Supplement section for this page.

103	caption		add comma after "Oklahoma,"
107	Eq.(5.40)		remove the bold print from $\mathbf{r}_1^4$ and in the factor $\lvert W(r_o,\mathbf{r}_1)\rvert$; θ and ϕ need to have the subscript 1 appended to be consistent with symbols in Fig.5.11, and add the subscript "s" to W to be consistent with Eq.4.9c.
108	1	1	change "stationary" to "steady"
	1	11	change "$d\overline{P}$" to "$E[dP]$".
	Eq. (5.42)		change "$d\overline{P}(v)$" to "$E[dP(v)]$
		15	change "$\overline{P}(\mathbf{r}_0,v)$" to" $E[\Delta P(\mathbf{r}_0,v)]$"; add comma after "by definition,"
	Eq.(5.43)		change "$\overline{P}(\mathbf{r}_0,v)$" to" $E[\Delta P(\mathbf{r}_0,v)]$"
	3	2-3	change to read: "…..by new ones having different spatial configurations, *the estimates* $\hat{S}(\vec{r}_o,v)$ *of* …"
109	1	4	remove comma after "replenished"
	Eq.(5.45)		change "$\overline{P}(\mathbf{r}_0)$" to "$E[P(\mathbf{r}_0)]$"
	4	1	add subscript "I" to $\overline{\eta}$ so it reads as "$\overline{\eta}_I(\mathbf{r}_0)$"
		2	delete footnote "4" at the end of this line
	Eq.(5.46a)		add subscript "I" to $\overline{\eta}$ on the left side of this equation.
112	Eq.5.57		add the subscript "s" to W in order to be consistent with Eqs.4.9c and 5.40 (modified)
113	1	1-4	change to read: "Assume scatterer velocity is the sum of steady $v_s(\mathbf{r})$ and turbulent $v_t(\mathbf{r}, t)$ wind components. Each contributes to the width of the power spectrum (even uniform wind contributes to the width because radial velocities vary across V_6; steady wind also brings new...."
	2	10-18	delete the sentences beginning with "Furthermore, we assume..." and ending with "...scatterer's axis of symmetry)."
	Eq. (5.59a)		change to:

$$
\begin{aligned}
R(mT_s) &= E[V^*(\tau_s,0)V(\tau_s,mT_s)] \\
&= E\left[\sum_i \sum_k F_i^*(0)A_i^*(0)F_k(mT_s)A_k(mT_s)\exp\{j(\phi_i - \phi_k - 4\pi v_k mT_s / \lambda\}\right] \qquad (5.59a) \\
&= \sum_k E[A_k^*(0)A_k(mT_s)F_k^*(0)F_k(mT_s)\exp\{-j4\pi v_k mT_s / \lambda\}]
\end{aligned}
$$

Following this equation retype the text up to and including Eq. (5.59c) as follows:

The expectation in Eq. (5.59a) includes the ensemble of statistically stationary and homogeneous turbulent velocity fields. The expectations of the off diagonal terms of the double sum are zero because the phases (φ_i ! φ_k) are uniformly distributed across 2π; thus the double sum reduces to a single one. To simplify further analysis, assume that the weighted scatterer's cross section F_kA_k is independent of v_k, and that F_k does not change appreciably [i.e., $F_k(0)$.$F_k(mT_s)$] while the scatterer moves during the time mT_s. Furthermore, assume A_k varies randomly in time (i.e., a hydrometeor may oscillate or change its orientation relative to the electric field). Thus Eq. (5.59a) reduces to

$$R(mT_\mathrm{s}) = \sum_k R_k(mT_\mathrm{s}) \,|\, F_k \,|^2 \; E[\exp\{-j4\pi v_k mT_\mathrm{s} / \lambda\}] \qquad (5.59b)$$

where

$$R_k(mT_s) = E[A_k^*(0)A_k(mT_s)]$$

Because $R(0)$ is proportional to the expected power E[P], and because

$$E[P(\boldsymbol{r}_0)] = \sum_k \sigma_{\mathrm{b}k} I(\boldsymbol{r}_0, \boldsymbol{r}_k) \qquad (5.59c)$$

114 2 2-4 modify to read: "...mechanisms in Eq. (5.59b) act through product terms. Furthermore, the *k*th scatterer's radial velocity v_k can be expressed as the sum of the velocities due to steady and turbulent winds that move the scatterer from one range position..."

6-13 delete these lines and replace with:

Eq. (5.59b), the velocities $v_s(\boldsymbol{r})$ and $v_t(\boldsymbol{r}, t)$ associated with steady and turbulent winds can each be placed into separate exponential functions that multiply one another. Thus the expectation of the product can be expressed by the product of the exponential containing $v_s(\boldsymbol{r})$ and the expectation of the exponential function containing $v_t(\boldsymbol{r}, t)$. The Fourier transform of $R(mT_s)$, giving the composite spectrum $S(f)$, can then be expressed as a convolution of the spectra associated with each of the three functions of lag mT_s.

115 1 1 change Eq.(5.59a) to Eq.(5.59b)

2 2 change to: "....to the air) the expected (over the ensemble of turbulent velocity fields) normalized power spectrum

$$E[\hat{S}_n(\boldsymbol{r}_0, v)] = \frac{E[\hat{S}(\boldsymbol{r}_0, v)]}{\int_{\infty}^{\infty} E[\hat{S}(\boldsymbol{r}_0, v)]dv} \qquad (5.60)$$

3 1 change to read: "......the autocorrelation $R_k(mT_s)$ would..."

7, 9 change Eq.(5.59a) to Eq.(5.59b)

3 14-15 Change these lines and Eq. (5.64) to read: "Because the correlation coefficient is related to the normalized power spectrum through Eq. (5.19), and because the Doppler shift $f = -2v/\lambda$, $\rho(mT_s)$ can be expressed as

$$\rho(mT_s) = \int_{-\lambda/4T_s}^{\lambda/4T_s} \frac{2}{\lambda} E[\hat{S}_n^{(f)}(-2v/\lambda))]e^{-j4\pi vmT_s/\lambda} dv$$

$$= \int_{-v_a}^{v_a} E[\hat{S}_n(v)]e^{-j4\pi vmT_s/\lambda} dv, \qquad (5.64)$$

116 0 1-4 change these lines to read: where $S_n^{(f)}(-2v/\lambda)$ is the normalized power spectrum in the frequency domain folded about zero, $S_n(v)$ is the normalized power spectrum in the Doppler velocity domain, and the two power spectra are related as

$$S(v) = \frac{2}{\lambda} S^{(f)}(-2v/\lambda). \qquad (5.65)$$

By equating Eq. (5.63) to Eq. (5.64), and assuming all power is confined to the Nyquist limits, $\pm v_a$, it can be concluded that

$$p(v) = E[\hat{S}_n(v)] \; . \qquad (5.66)$$

116 1 1-3 change to read: "Thus, for homogeneous turbulence, at least homogeneous throughout the resolution volume V_6, the *expected* normalized power spectrum is equal to the velocity probability distribution. Moreover, it is independent of reflectivity and the angular and range weighting functions.

1 3-7 Delete the last two sentences beginning with “Although, in deriving….”

2 19 change to read: “where σ_s^2 is due to shear of steady wind v_s, σ_α^2 to..”

117 2 4-7 Modify these lines to read: “where the terms are due to shear of v_s along the three spherical coordinates at $\mathbf{r}_0$. In this coordinate system (5.70) automatically includes…”

9 change to read: “the so-called beam-broadening term;....”

3 Replace the text in this paragraph up to and including Eq. (5.75) with: ASpherical coordinate shears of v_s can be directly measured with the radar and it is natural to express σ_s^2 in terms of these shears. If the resolution volume V_6 dimensions are much smaller than its range r_0, and angular and radial shears are uniform, v_s within V_6 can be expressed as

$$v_s - v_0 \approx k_\varphi r_0 \sin\theta_0 (\varphi - \varphi_0) + k_\theta r_0 (\theta - \theta_0) + k_r (r - r_0) \qquad (5.71)$$

provided $\theta_1 << 1$ (radian) and $\theta_0 >> \theta_1$, where

$$k_\varphi \equiv \frac{1}{r_o \sin\theta_0} \frac{\partial v_s}{\partial \varphi}, \quad k_\theta \equiv \frac{1}{r_o} \frac{\partial v_s}{\partial \theta}, \quad k_r \equiv \frac{\partial v_s}{\partial r} \qquad (5.72)$$

are angular and radial shears of v_s. Angular shears are present even if Cartesian shears are non-existent, and are functions of $\mathbf{r}_0$. For example, if wind is uniform (i.e., constant Cartesian components u_0, v_0, w_0),

$$\frac{\partial v_s}{\partial \phi} = (u_0 \cos\phi_0 - v_0 \sin\phi_0)\sin\theta_0; \quad \frac{\partial v_s}{\partial \theta} = w_0 \sin\theta_0 - (u_0 \sin\phi_0 + v_0 \cos\phi_0)\cos\theta_0; \quad k_r = 0 . \qquad (5.73)$$

If reflectivity is uniform and the weighting function is product separable and symmetric about $\mathbf{r}_0$, substitution of Eq. (5.71) into Eq. (5.51) produces

$$\sigma_s^2(\mathbf{r}_0) = \sigma_{s\theta}^2 + \sigma_{s\phi}^2 + \sigma_r^2 = k_\theta^2 r_0^2 \sigma_\theta^2 + k_\phi^2 r_0^2 \sin^2\theta_0 \sigma_\phi^2(\theta_0) + k_r^2 \sigma_r^2 . \qquad (5.74)$$

Because lines of constant ϕ converge at the vertical, the second central moment $\sigma_\phi^2(\theta_0)$ of the two-way power pattern is $\sigma_\phi(\theta_0) = \sigma_\phi(0)/\sin\theta_0$, where $\sigma_\phi(0)$ is the intrinsic beamwidth; σ_r^2 is the second central moment of $|W(r)|^2$. For circularly symmetric Gaussian patterns,

$$\sigma_\theta = \frac{\theta_1}{4\sqrt{\ln 2}}\ ; \quad \sigma_\phi(\theta_0) = \frac{\theta_1}{4\sqrt{\ln 2}}\frac{1}{\sin\theta_0} \qquad (5.75)$$

122	3	2, 3	change to read "...signals, estimates using few samples have a large statistical uncertainty and therefore don't allow meaningful ...."
125	1	1	replace “average” with “expected”
	Eq. (6.5)		append to this equation the footnote: “In chapter 5 ρ is the complex correlation coefficient. Henceforth it represents the magnitude of this complex function.”
	4	5	remove the overbar on P, S, and N
126	3	2	change “ $\overline{P}$ ” to “ $\overline{S}$ ”.
	3	2-4	the second sentence, modified to read, "The P_k values of meteorological interest...meeting this large dynamic range requirement", should be moved to the end of the paragraph 1
		5	change “ $\overline{P}$ ” to “ S ”.
		10	change “$E(P)$” to “ $E[\hat{P}]$ ”
127	0	1-2	remove the overbar on P in the three places
	3	1	remove the overbar on Q
		3	change σ_Q^2 to $\sigma_{\hat{Q}}^2$, (i.e., the subscript Q needs a (^) over it)
	Eq.(6.9)		left side: place hat (^) over Q
		5	place hat (^) over Q in σ_Q^2
		8	delete the citation “(Papoulis, 1965)”
128	1	8	change “unambiguous” to “Nyquist”
	2	4-7	rewrite the three sentences after Eq. (6.12) as: “For large M and $\sigma_{vn} << 1$, $M_I = 2M\sigma_{vn}\pi^{1/2}$. The variance of S estimated from M samples is calculated using the distribution given by Eq. (4.7) in which $S \equiv P$ (this gives, in Eq.

			(6.10), $\sigma_Q^2 = S^2$), and calculating M_I from Eq. (6.12). Thus the standard deviation of a M-sample signal power estimate is $S / \sqrt{M_\mathrm{I}}$.”
	Eq.(6.12)		the subscript 1 on M on the left side of this equation should be “I”
	3	1-2	change to read “To estimate *S* in presence of receiver noise, we need to subtract.....”
129	0	5-6	change last sentence to read: ....then the number of independent samples can be determined using an analysis similar to.....
130	Table 6.1		add above **“Reflectivity factor calculator”** the new entry “**Sampling rate”,** and in the right column on the same line insert “0.6 MHz". Under "**Reflectivity factor calculator**", "Range increment" should be “0.25 km” and not “1 or 2 km”. But insert as the final entry under "**Reflectivity factor calculator**" the entry “Range interval Δr”, and on the same line insert “1 or 2 km” in the right column.
	1	1	change to “Sometimes the bandwidth of the receiver is about…”
134	1	1	the first line before Eq.(6,22a) should read: If σ_{vn}<<1, but condition (6.20a) satisfied, the sum in Eq.(6.21)......
	Fig.6.5		on the plot change $\geq$ 20 dB to $\geq$ 15 dB
136	footnote		change to read: To avoid occurrence of negative $\hat{S}$, only the sum in Eq. (6.28) is used but it is multiplied with $S\hat{N}R / (S\hat{N}R + 1)$
137	1	3	change to read: “..... it can be seen that the standard error of the estimates are relatively independent of SNR and σ_{vn} as long as $0.02 < \sigma_{vn} < 0.2$ and SNR $\geq$ 15 dB.”
	2	1	delete “($\sigma_{vn} > 1/2\pi$)”
146	1	4	change unit to read “less than 1 dB”, not “dBZ”
	Eq.(6.48)		$\lvert\rho(mT_\mathrm{s})\rvert^2$ should be $\lvert\rho(2mT_\mathrm{s}\rvert^2$
150	Eq.(6.50)		change i - 1 below the summation sign to i = 1.
	1	4	change to read: “...= $-2T_\mathrm{s}(k + k_v)v$ ....”

		6-8	change to read: ”.... scattering; k_h and k_v are increments, due to the presence of hydrometeors, added to the propagation wavenumber k of the atmosphere. The phase of R_b is......”
		9,11	change k_o to k
151	0	7	change $\lvert\rho_{hv}(0)\rvert$ to $\lvert\rho_{hv}(0)\rvert^2$
	Eq.(6.57)		The second equation should be multiplied by $\lvert\rho_{hv}(0)\rvert^2$
155	3	3	in section 6.8.5 line 3, change “Because” to “If”
156	1	12-15	change to read: “A normalized standard deviation is plotted in Fig.18 for a slightly simpler estimator in which the ......in (6.66) is not used. Inclusion of these terms.....”
160	2	6	change “unambiguous velocity ” to “Nyquist velocity”
164	2	3	at the end of this line add “(from Eq.3.40)”
171	0	3	T_s should be T_2
172	1	2	at the end of this line add “....the true velocity v_t is the least common multiple of $v_{\mathrm{a}1}$, $v_{\mathrm{a}2}$. Thus”...
		4	delete “v_t is the true velocity,”
173	0	1	change to read: “…velocity interval ± v_m for this….”
	Eq. (7.6b)		place ± before v_m
	3	9-11	change “unambiguous” to “Nyquist” at two places, and change “An unambiguous velocity” to “A Nyquist interval”
176	1	2	“PTR” should be “PRT”
182	Eq.(7.12)		W_iW_{i+1} should be W_iW_{i+l}
197	1	1	“though” should be “through”
	2	4	“Fig.3.3" should be “Fig.3.2"
198	0	18	change “Pate” to “Plate”

		19	replace “10 dBZ” with “20 dBZ”
200	Fig.7.28		correct caption to read as: The WSR-88D antenna pattern in the vertical plane, the polarization was circular but has since been changed to linear, and the antenna was without a radome. Sidelobes with radome are specified to be below the dashed envelope. Subsequent measurements suggested that the radome increases the near (i.e., $\pm 5^{\circ}$) sidelobe levels by less than 2 dB and has negligible effect on the main lobe. (Note: the dashed lines are incorrectly drawn in the second edition, first printing. They should extend from -26 dB at $\pm 2^{\circ}$ to -38dB at $\pm 10^{\circ}$, and then the constant level should be at -42 dB)
201	0	2	“Norma” should be “Norman”
205	2	4	Eq.(5.61) should be Eq.(5.69)
209	1	1	put “by radar” at the end of the sentence after “precipitation”
215	3	5	“Foot” should be “Foote”
		11	insert “up to”{ before the quantity 800 kg m^{-3}
		12	add comma after “frozen particles,”
216	Eq.(8.2)		change period to comma and add the following after the equation: “for a range of Λ from about 0.1 to 1 mm^{-1}.
	1	10	change to read “...and Kinzer. Nevertheless, we shall...”
217	0		in lines 1,2,3,8, and 12 change ρ to γ. In line 1 add γ after “...air density”. But ρ_h in line 12 (i.e., Eq.(8.6a) remains as is.
222	2	2	$N_A(D)$ should be d$N_A(D)$, and the same correction applies to Eqs.(8.17) and (8.18); the differential dD on the left side of Eq.(8.18) must be deleted.
223			in title of section 8.4 change “measurement” to “measurements”
228	1	2-5	change to read: First, the radar equation, Eq. (4.35), retrieves an estimate of the reflectivity factor Z_e of water drops. If the scatterers are ice spheres, then Z_i is obtained from Z_e by using the following equation: $Z_i = (\lvert K_w\rvert^2/\lvert K_i\rvert^2)Z_e$. (8.24)
		10-17	change to read: “...is immaterial and the value forline K sub i line sup 2 is 0.176. But researchers (e.g., Sekhon and Srivastava, 1970) usually express

the drop size distributions in terms of the diameter of the melted particle. The diameters of melted particles are smaller by a factor of $0.92^{1/3}$ (0.92.....) and thus must be increased by a factor of 1.028 in order to obtain the drop size distributions of equivalent ice spheres (Smith, 1984).

2 1-6 replace this paragraph with: For example, the Sekhon-Srivastava (1970) R, Z relation for snow is

$$Z = 1780 R_s^{2.21} \; . \tag{8.25a}$$

But this needs to be multiplied by $(1.028)^6$ to obtain

$$Z_i = 2103 R_s^{2.21}$$

the reflectivity factor of the ice particles. Eq. (8.25b) is the appropriate relation that must be used to estimate the equivalent rainfall rate R_s (mm/hr) from the Z_i measured by radar. To obtain radar measured Z_i, Eq. (8.24) should be used in Eq. (4.35).

228 Eq.(8.26a) change the period to a comma and add the following: “where Λ lies in the interval from about 0.1 to 1 mm^{-1}.

3 7 change “Eq.(8.14)” to “Eq.(8.15)”

Eq.(8.26b) change to:

$$Z_H = \frac{115}{\Lambda^{3.37}} \gamma(7, \Lambda D_{\max}) \tag{8.26b}$$

229 2 1 change “poduces” to “produces”

Fig. 8.8 remove subscript to unit “dBZ”; add “MDT” after time of 1535

230 1 1 delete “Strong scattering capable to produce ...”, and start paragraph with: “The three-body signature is ...”

232 0 10-11 change to: ...microwave (λ = 0.84 cm) path....

234 1 5 add comma after “(Fig. 8.1),”

Eq.(8.30) right bracket “}” should be matched in size to left bracket “{”

2 4 (8.7) should be (8.8)

240 2 2 change to read: “...located at r_n. Using Eqs.(2.3), (3.20), and (3.24), it can be shown that....”

		5	change to: “...k is the precipitation-free atmospheric wave number, P_j is ..”
		7	change to: “...is the rms received field. The magnitude of ....”
		10	place expectation brackets around $\lvert s_{ij}\rvert^2$. This should look like $<\lvert s_{ij}\rvert^2>$.
241	0	4-5	change to read: ...is zero because the phase $2kr_n$ is uniformly distributed over 2π. Thus, radar.....
	Eq.(8.44a)		Eq.(8.44a) and the lines following it should read as follows: $= \int n(\boldsymbol{r}) < s_{ij} s^*_{kl} > \lvert F(\boldsymbol{r})\rvert^2 \, dV$ In the last equality the summation over n is replaced with the integral over the product of the density $n(\boldsymbol{r})$ of drops at position $\mathbf{r}$, the ensemble average of $s_{ij}s_{kl}$,and the resolution volume weighting function.
242	2	2	change sentence to read “The number of attributes....”
	3	1-2	change to read: Variables in this list are combinations of the three real diagonal terms and one complex off diagonal term. The other two complex terms have been less.......
244	3	3	change to: ...s_{vv}, and s_{rr} given by Eq.(8.52a) is zero;..
245	0	8	s_{lr} should be s_{rr}
248	Eq.(8.57)		parenthesize “)” needs to be placed to the right of the term “(b/a”
249	2	2	change Prat to Pratt
	Eq.8.58		$\cos^2\delta$ should be $\sin^2\delta$; replace k_o with k; p_v and p_h should be replaced with p_a and p_b respectively
	Eq.8.59a,b		change the subscripts h to b, and v to a
	2	9	change to read: p_a and p_b are the drop’s susceptibility in generating dipole moments along its axis of symmetry and in the plane perpendicular to it respectively, and e its eccentricity,
		12-13	rewrite as: ...symmetry axis, and ψ is the apparent canting angle (i.e., the angle between the electric field direction for “vertically” polarized waves (**v** in Fig.8.15) and the projection of the axis of symmetry onto the plane of polarization. The forward........

		17	modify to read: $f_h = k^2 p_b$, and $f_v = k^2 [(p_a-p_b)\sin^2\delta+p_b]$ (Oguchi, ...
	3	4-5	Rewrite as: Hence from Eqs.(8.58) an oblate drop has, for horizontal propagation and an apparent canting angle equal to zero, the following cross sections for h and v polarizations:
250	Fig.8.15		change caption to read : “the linear polarization base vectors, and ψ' and ψ are the canting and apparent canting angles of the scatterer. The vector ....x, z plane, and **h** is parallel to the y axis. ψ is positive if n’ is ccw from **v.**”
254		6	change to “...the data collection period, ...”
264	2	13	change “;” to “.” and start new sentence “Instead...”
266	1	1	replace “the reduction” with “a reduction”
		2	replace “is due..” with “would be due...”
		3	replace sentence beginning with “The drop..” with “In general the change in the composite $\|\rho_{hv}(0)\|$ depends on the relative reflectivities, differential reflectivities, and the $\|\rho_{hv}(0)\|$s of the precipitation types.”
268	Fig. 8.29		LDR_{hv} on the ordinate axis should be LDR_{vh}
	0	1, 4	change LDR_{hv} to LDR_{vh} at the two places it appears in this paragraph.
269	Fig. 8.30		In the caption, change LDR_{hv} to LDR_{vh} at the two places it appears.
270	0	1	insert "...the presence...."; add comma after "...diameter),"
272	1	2	change "survy" to "survey"
274			change title of section 8.6 to: "**Size Distributions derived from Doppler Spectra**"
275	1	9	"spectrum-broadening contributions"
	1	10	change to: “.....from Eqs. (3.6) and (4.31), can be....
277	0	6	add comma after "At this wavelength,"
	0	16	change “23000” to “230,000”

278	Fig. 8.36		add to figure caption: "*N*(*D*) is in $\mathrm{m^{-3}mm^{-1}}$ if 10 is added to the ordinate values."
288	1	11	"shelf-like cloud"
289	2	3	delete the sentence beginning with “In this chapter overbars….”
	2	13	change to read: "...[from Eq.(8.5)] to account..."
292	2	5	"...phenomena are..."
294	Fig.9.4b		along the x axis the value “East 49.7" needs to be “East 44.7"
297	2	12, 14	remove periods in time abbreviations (i.e., "CST", not C.S.T.", etc.) here and throughout the text
298	Fig.9.4a,b		here and elsewhere in the text, remove periods in time abbreviations (i.e., should be: "CST", not C.S.T.")
304	1	2, 3	Delete hyphens between "three-Doppler" and "dual-Doppler" and add radar after "dual Doppler radar"
307	1	1	change this paragraph to be a continuation of the previous one and modify it to read: "where θ'_e, the angle between the radar beam and the tangent plane below the data point, is the sum of ....."
	2	15	Sentence beginning with "If the ground below..." should be changed to read: "Eq. (9.11) can be generalized (i.e., wind can have any z dependence) and yet greatly simplified if the wind is linear on spherical surfaces and γ_o depends only on z (Problem 9.9)."
		19	insert v_z
309	3	3	"...if data are..."
313	1	10	change to "which, for r constant, can be solved.."
		16	change to "wind above it."
328	3	3	interchange word order to read "..by simultaneously displaying...."
338	Eq (9.33)		subscript on right side should be "t" instead of "r"
361	1	11	change "whch" to "which"

362	2	7	add comma after "...Arkansas,"
370	Fig 9.43		delete the last sentence of the caption
376	1	4	add comma before ", causing it to flow...."
386	2	2	change comma to semicolon after "...atmosphere; however, ..."
385	Prob. (9.9)		Change to read: "Show that wind can have any z dependence and $w_x = w_y = 0$ if wind is horizontally linear and satisfies the anelastic continuity equation, Eq.(9.5b). Under these conditions show that the number of unknowns in Eq.(9.11) reduces from 11 to 6!"
387	1	7	put period between right parenthesis and right bracket "...Eq.(5.48).]"
389	2	2	delete “towers or even”
390	0	1	change to read “along the path **P** of the aircraft, and $S_{ij}(K_P)$ is the Fourier transform of $R_{ij}(\mathbf{P})$. In contrast....”
391	0	1	append adjective to "Bessel function" so the line reads: where $K_v(\rho/\rho_o)$ is the modified Bessel function....
393	Eq.(10.29)		add an additional subscript to ρ_0 so that it reads as ρ_{0i}
	1	10, 11	change to read: "where the indices ii identify either the transverse or the longitudinal component. Furthermore, because $R_{PP}(0) = R_{tt}(0) / R(0)$ for isotropic turbulence, ρ_{oi} is the only parameter that differs for transverse and longitudinal correlations. For small values of $\rho << \rho_{oi}$..."
Eqs. (10.30), (1032)			delete the subscripts “*ii*” on *R*, and add the subscript “*i*” to ρ_0 so that it reads as ρ_{0i}
	1		delete last sentence beginning with " Furthermore,.."
	Eq. (10.33)		place subscript *l* on *C* so that it reads C_l.
394	0	1	change to read: “where C_l^2 is a dimensionless parameter with a value of about 2.”
	Eq.(10.37)		change to read:

$$R_{ii}(\rho, \tau_1 = 0) = R(0)[1 - (\rho / \rho_{oi})^{2/3}] \tag{10.37}$$

Eq.(10.38)			change the first equal sign to ..
	4	4	modify to read: "....where $K\rho_o >> 1$ has been assumed, and the subscript..."
398	1	12	change to read: "…of the weighting function I_n, and $\Phi_v(\mathbf{K})$ is the spectrum of point velocities."
	1	16	$\mathbf{K}_1$ should be K_1
401	Fig. 10.6		in caption: Eq.(5.67) should be Eq.(5.75); the parameter along the abscissa needs to be changed to $K_1/2\pi$; and add to caption: "The curves are normalized by $S_P(0)$ for $K_o = 2\pi$ rad km^{-1}."
403	1	5	change to read: "...spectrum width, σ_t (Eq.5.67), due to turbulence, is given by Eq.(5.51) in which steady wind is assumed not to be present. Thus,"
	Eq. (10.56)		in this equation replace the subscript "v" with "t"; the lines after this equation should read: "where the ..... average of turbulent velocities weighted by $I_n(\boldsymbol{r}_0,\boldsymbol{r})\eta(\boldsymbol{r})$. The variance…"
	Eq.(10.59)		change the first subscript "v" to "t"
	0	10	change to read: "the ensemble average of σ_t^2 and the variance of the turbulent velocities weighted spatially by..."
	1	1	delete the phrase "is independent of the weighting function but" in the first sentence.
	2		"In addition.....energy, the two variances σ_t^2 and $\sigma_{\bar{v}}^2$ have relative magnitudes that depend on $I_n(\boldsymbol{r}_0,\boldsymbol{r})\eta(\boldsymbol{r})$. These two variances describe…..".
	4	7	place an over bar on the subscript "u" in the next to last equation
405	2	2	replace σ_v with σ_t
Eqs.(10.61), (10.62)			replace σ_v^2 with σ_t^2

	3	1	replace $\sigma_v^2(\phi)$ with $\sigma_t^2(\phi)$
408	2	8	replace $<\sigma_v^2>$ with $<\sigma_t^2>$
	Eq.(10.65)		replace $<\sigma_v^2>$ with $<\sigma_t^2>$
409	1	1	replace "the Doppler spectrum width" with σ_t
		2	replace σ_v with σ_t
	2	4	replace σ_v with σ_t
		5	change to read: "...range resolution equal to or smaller than...."
	Eq.(10.67)		replace σ_v^2 with $<\sigma_t^2>$
	Eq.(10.68)		replace σ_v^3 with $<\sigma_t^2>^{3/2}$
	3	1	replace σ_v^2 with $<\sigma_t^2>$
	Eq.(10.70)		replace σ_v^3 with $<\sigma_t^2>^{3/2}$
410	last	last	change sentence starting with "An example ….." to "In Fig.10.10 is an example of a radial velocity field in a thunderstorm which exhibits areas of large shear."
411	0	3	change to "...shear region is near the mesocyclone..."
412	2	2	change “plane surface” to “linear model”
		5, 7	change “surface” to “model”
	3	1	change “surface” to “model”
		3	insertion: “...origin of the fitting surface.”
413	0	6	change to read “...to these uniform shears..”
414	0	1	space between "the up_" and "(down_)"
418	1		insert at the end of the paragraph: "Pilots consider turbulence to be severe if $\varepsilon \geq 0.1$ m^{2}s^{-3} (Trout and Panofsky, 1969)"

419	Fig. 10.18		The "-5/3" slope line drawn on this figure needs to be redrawn to have a -5/3 slope. Furthermore, remove the negative sign on "s" in the units (m^3/s^{-2}) on the ordinate scale; this should read (m^3/s^2).
423	0	14	(just after Eq. 8) change to "... the mean flow energy budget equation."
426			change section title to: Formulation of the Wave Equation for Inhomogenous and Random Media
427	Eq.(11.10)		delete the period at the end of the equation and add: where $c = \sqrt{\mu_0 \varepsilon_0}$ is the speed of light in a vacuum.
428	1	last	change to: ".. $k_0^2 \equiv \omega_0^2 / c^2$, where k_0 is the wavenumber in vacuum.
431	2	13, 16	change "scatter" to "scattering"
	Eq.11.20		τ needs to be replaced by t.
432	0	2	delete "when the beams intersect"
	0	5	change to: ...if the pulse widths and receivers are the same
	Eq.11.27		delete the term $e^{-jk_0 r_r}$
	2	20	start new paragraph at the line beginning with "With the proviso..."
433	2	1	change: "...antennas, and typical ranges and time resolutions used..."
		4	insert the following after Eq. (11.31c): …, here and henceforth we drop the $e^{j\omega_0 t}$ term.
434	0	16	change to: Applying the divergence theorem to $\phi\mathbf{u}$, and the argument following Eq.(11.33), the equation (11.39)
	Eq.(11.42)		the third unit vector $\mathbf{a}_{ro}$ should be $\mathbf{a}_{to}$
435	4	last	this line should end with a comma
436	0	1	change "Equation (11.46)" to "Inequality (11.46)"

	2	4	change to read: "....smaller subvolumes (i.e., Bragg scatterers having dimensions.........."
		5, 6	change to read: "...The scattered fields from these sub volumes add incoherently...."
437	0	2	for consistency change "scatter" to "scattering"
		4	should read "substitution of Eqs...."
445/446			to avoid possibly confusing the <u>B</u>ragg wavelength with the <u>o</u>uter scale (e.g., Chapter 10 and Fig.11.8), change all Λ_o to Λ_B , and all K_o to K_B; also change τ_o to τ_B.
445	1	6	delete "time dependence of the"
447	Eq.(11.79)		L_z should be L_x only in the first line of Eq.(11.79).
448	1	3	change "when" to "if"
	2	5	to have Fig.11.8 relate explicitly to the text, it is suggested to modify this line to read: "....$2L_y$, $2L_z$, and assume $\mathbf{q} = \mathbf{K} - \mathbf{a}_z k_o m_z$."
	2	7	after Eq.(11.85a) replace "whose first ...." with: "where $q_z = K_z - k_o m_z$. $F(\mathbf{q})$ has first zeros at $K_x = \pm\frac{\pi}{L_x}, \quad K_y = \pm\frac{\pi}{L_y}, \quad K_z = k_0 m_z \pm \frac{\pi}{L_z}. \qquad (11.85b)$ The regions of wavenumber space over which $F(\mathbf{q})$ is appreciable is of the order of $\frac{\pi^3}{L_x L_y L_z} = \frac{8\pi^3}{V} \equiv \mathrm{Y}$
450	1	6	change to "Because $m_x = m_y = 0$, the point ($K_x = 0$, $K_y = 0$, $K_z = k_o\,\lvert\mathbf{m}\rvert$) locates the position...."
452	3	2	change "scatter" to "scattering"
453	1	6	modify sentence beginning with "The assumptions needed are...." to read: "The assumption needed is that the Bragg scatterer's correlation lengths transverse to **m** (Fig.11.10) must satisfy....".
Eqs.(11.105)			

and (11.106)			The subscript "c," should be replaced by subscript "B"
	Eq.(11.106)		the square root radical sign needs to be extended over π.
		12	Here and everywhere in the text remaining throughout the book, replace "blob(s)" with "Bragg scatterer(s)".
		12, 13	change subscript "c" to "B"
		14	Insert the sentence: “A Bragg scatterer is defined by correlation lengths of the refractive index irregularities *at the Bragg wavelength*; these lengths are inversely proportional to the width of Phi sub n(bold K) at the Bragg wavenumber.”
	Eq.11.107		replace the comma at the end of this equation with a period
	Fig.(11.10)		Here and everywhere in the text remaining throughout the book, replace "scattering blob(s)" with "Bragg scatterer(s)". For example, the caption should read "A Bragg scatterer with a size determined by its correlation lengths. The Bragg scatterer is assumed to..". Furthermore, figure 11.10 needs to be redrawn to change "Scattering blob" to "Bragg scatterer", and subscripts "c" to "B"
454	0	0	delete the first line and modify the first sentence to read: "The phase is quadratic.....to **m** and nearly linear in **r** along **m**.". After this sentence insert the following: "But under condition (11.107), the phase in the plane perpendicular to **m** is essentially uniform across the Bragg scatterer.
	Fig.11.11		caption should be changed to read: “........, a receiver, and an elemental scattering volume dV_c.”
		6	change subscript "c" to "B"
	Eq.(11.109)		the label is missing for the equation between Eqs. (11.108) and (11.110)
455	0	2	the phrase "of the common volume V_c " should be placed after Eq.(11.111), but delete "V_c" in this phrase.
456	Eq.(11.115)		"P_r" should be "P_t". Absolute sign around W(r) should be removed, and the bold ***r*** should not be bolded.
Fig. 11.12			add a unit vector $\mathbf{a}_o$ drawn from the origin “**O**” along the line “r_0”.
458	1	last	because 10! might be confused with ten factorial, change "10" to "ten"

	2	4	make a footnote after $\sqrt{2}$ to read: z' is the projection of r' onto the z axis; not to be confused with z' in Fig.11.12 which is the vertical of the rotated coordinate system used in section 11.5.4.
459	1	4	change "production" to "proportion"
		5	change word order to read "...(the larger $\sigma_\perp$ or σ_r are compared to....)"
	2	1	indent paragraph beginning with "Because we have..."
	3	10	modify sentence after condition (11.124) to read: If condition (11.124) is not satisfied, the Fresnel term in....
		11	start new paragraph with sentence beginning with "Gurvich and Kon..." and delete the word "also".
		15	delete the word "near" and the parentheses around the word "Fresnel". ("near" commonly refers to the region within an aperture diameter away from the antenna)
459	Eq. (11.125)		delete the subscript "c" in this equation, as well as that attached to ρ_{ch} in the second line following Eq.(11.125) so that it reads "ρ_h".
459-460			Everywhere on these two pages delete the subscript c if attached to ρ.
460	1	4-9	delete the third to fifth sentences in this paragraph and replace with the following: Condition (11.124) is more restrictive than (11.106); if (11.124) is violated the Fresnel term is required to account for the quadratic phase distribution *across the scattering volume*, whereas (11.106) imposes phase uniformity *across the Bragg scatterer*; this latter condition is more easily satisfied the farther the scatterers are in the far field (also see comments at the end of section 11.5.3).
		9	start new paragraph with sentence beginning with: "If $\rho_\perp$ is much...."
461	Eq. (11.130)		change "$<P_t>$" to "$<P_r>$"
461	0	4	delete "along ρ" in this line.

462	2	2	alter this line to read: "Thus for a vertically directed beam and anisotropic....."
		3	It would be clearer to state: "For a radar beam pointed in the horizontal direction,...."
		5, 13	delete "linear"
		7	delete the sentence beginning with "Only when this...." (comment: this sentence gives an erroneous interpretation because we have stated on p.459, para.2, that in the far field the resolution weighting function can be ignored if the Fresnel term can be ignored; that is, in the far field the sampling function $F(\mathbf{K})$ is principally dependent on the Fresnel term. Because of the reciprocal relations between spectral widths and correlation widths, however, even if the Fresnel term in Eq.(11.122) can be ignored, its spectral counterpart $F(\mathbf{K})$ cannot be ignored)
463	Eq.(11.133)		to be consistent with Fig.11.12, Eq.(11.133) should read:
			$\delta'_x = \delta_x \cos\psi + \delta_z \sin\psi,\ \ \delta'_y = \delta_y,\ \ \delta'_z = -\delta_y \sin\psi + \delta_z \cos\psi \qquad (11.133)$
464	Fig. 11.14		caption: the first citation is incorrect. It should read: “(data are from Röttger et al., 1981)”. Furthermore, delete the last parenthetical expression: “(Reprinted with permission from ….).”
	1	7	add comma after "...refractive index, it is...."
465	1	2	change to "...passive additive (e.g., chaff) is..."
468	2	11	change “(11.109)” to “11.104”
471	4	4	the unit is missing its power in "5 x 10^{-13} $m^{-2/3}$..."
473	0	1	change to "...and about 30 times that...."
		6	add comma after "Kansas,"
478	0	2	change Eq.(3.12) to Eq.(3.21)
478	0	7	Change to read: “...the gain g. Then g, now the directional gain (Section 3.1.2), is related...”
		last	space between units to read "16 m s^{-1}."
479	2	2	add comma after "Virginia,"

481	2	last	add comma before ", and thus"
483	3	6-8	change to read: "...at the top of a stable layer that....about 300 m AGL. The second.....is at the base of another stable layer that extends from...."
	3	18	"...displacement is...."
484	Fig. 11.23d		date should be "14 July 1969", not "1979"
487	2	11	add comma after "...equal, coverage...."
		14	change to read: “frequencies) and by pulse width, which is longer at lower frequencies.”
489	0	4	change to read: “SNR, the ratio of peak signal to.....”
		5	change "time samples" to "*I*, *Q* samples"
493	1		delete the last sentence and make the following changes: 1) change lines 2 and 3 to read: “... $C_n^2 = 10^{-18}$ m$^{-2/3}$ (Fig.11.17), the maximum altitude to which wind can be measured is computed from Eq.(11.152) to be about 4.5 km. 2) change lines 4 and 5 to read: “that velocity estimates are made with SNR = -19.2 dB (from Eq.11.153 for $T_s = 3.13 \times 10^{-3}$ s), and that σ_v = 0.5m s^{-1}, SD(v) =1 m s^{-1}, and a system temperature is about 200 K (section 11.6.3).”
	2	1-4	change to read: “Assuming that velocities could be estimated at SNRs as low as -35dB (May and Strauch, 1989), the WSR-88D could provide profiles of winds with an accuracy of about 1 m s^{-1} within the entire troposphere if C_n^2 values…”
		8	change “14” to “12”
		9	change “able to measure” to “capable of measuring”
503	1	3	"10-cm wavelength..."
	Fig. 11.35		add to the caption: "The elevation angle was 4.5^{o}."
516		15	Eq. (C.14): a right parenthesis needs to be inserted in the first line of this equation

524			citation for the Bebbington et al. reference should be IEE, not IEEE
526			interchange the order of the Browning references
535	Refer.		add: Kristensen, L., 1979: On Longitudinal spectral coherence. *Boundary Layer Meteorol.,* **16,** 145-153.
537			Nutten, et al. Remove redundant "T" in "TThe Ronsard radars"
539			Rinehart, 1991: "Grand Forks", not "Grandd Forks"
540			alphabetically, Seliga follows Sekhon
		15	The year for the Sachidananda and Zrnic reference should be 1989 instead of 1988, and the volume number should be **6** instead of **4**.
545		23	change “Doviack” to “Doviak”
548	Index		"Beamwidth, one-way" citation should read 32-34.
551	Index		add "Far field, antenna, 32; scattering volume,435-436.
		12	Insert "Bragg scatterer's" in front of "correlation"
			change entry for Dwell time to: Dwell time, 124,127 (comment: delete the phrase “sample time averaging” and change page numbers)
554	index		add after "Matched Filters ...", 77, 80
558	index		Scattering geometry, common volume scatter: change page numbers to 453-456.
	index		add: Scatter angle, 436-437.
	index		Resolution volume, range weighting, 75-79; delete this entry (comment: nowhere on these pages is there a reference to the resolution volume). Replace with: Resolution volume, weather radar equation, 80-81.
559	index		add: "Spectrum width, weighted velocity deviations, 110: as a sum, 116-118."
560	index		add: unambiguous interval, 132

SUPPLEMENTS

The following supplements are provided at the indicated places to clarify and/or extend the text of "Doppler Radar and Weather Observations", Second Edition-1993.

33	1	4	change to read: …and often its intensity (i.e., power density) versus…
34		0	It might be of interest to note that the one-way radiation pattern of the WSR-88D radar (the network radar used by the Weather Service in the USA) can be approximated with $f^2(\theta) = \left(\frac{48.2 J_3(u)}{u^3} + \frac{0.32 J_1(u)}{u} \right)^2 / (1.16)^2$ which agrees to within 2 dB of the measured pattern down to about the -20 dB level. The pattern given by this equation is slightly broader than that measured for NSSL's research WSR-88D at a wavelength of 0.111m (i.e., the 3 dB beamwidth calculates to about 1° whereas the measured width is about 0.93°). This analytical expression is that obtained if the reflector's aperture is illuminated with a power density $[1-4(\rho/D_a)^2]^4$ on a uniform illumination level producing at the reflector's edge a power density 17.2 dB below the peak. Sidelobe levels, calculated from the above expression for angles from about 3° to 10° from the beam axis, are about 60 dB below the peak lobe. Measured sidelobe levels, however, can be anywhere from a few dB to about 20 dB larger than this level. The increased levels are due to blockage by the feed, its supporting spars, and the radome.
35	1		There are several definitions of cross sections. For example, $\sigma_d = \frac{S_r}{S_i} r^2$ is the *differential scatter cross section*; that is, it is the cross section *per unit* solid angle. Integration of $\sigma(\theta', \phi')$ over 4π steradians gives the *total scatter cross section* (see section 3.3).
36	0	2	Insert at the end of the first sentence: "It can be shown, using formulas presented in Section 8.5.2.4, that Eq. (3.6) has practical validity only if drops have an equivalent spherical diameter D_e less than 2 mm. Drops having D_e larger than 2 mm have backscatter cross sections differences larger than about 0.5 dB for horizontally and vertically polarized waves (i.e., $\sigma_h > 1.1\sigma_v$)."
44	3	4	Blake has more recently published (1986, in "Radar range performance analysis", 2nd ed., ARTECH House, Norwood, MA.) new values of

attenuation in gases. For example, at λ = 10 cm, r = 200 km, $\theta_e = 0^\circ$, the two way loss is about 0.3 dB larger than that given in Fig.3.6.

56 If the beam is passing through clouds and storms, Eq. (3.34) should be replaced by

$$T_{\mathrm{s}}' = \left(1 - \frac{1}{\ell_{\mathrm{c}}}\right)(1 - \chi + \chi\eta_{\mathrm{r}})T_{\mathrm{c}} + \frac{1-\chi}{\ell_{\mathrm{c}}}T_{\mathrm{s}} + \chi(1-\eta_{\mathrm{r}})T_{\mathrm{g}} + \frac{\chi\eta_{\mathrm{r}}}{\ell_{\mathrm{c}}}T_{\mathrm{s}}$$

where ℓ_{c} and T_c are the cloud's attenuation and temperature.

57 Fig. 3.11 For completeness, the ordinate should be labeled "Sky noise temperature T_{s} (K)"

71 2, 3 An explanation for the $\sqrt{2}$ factors in Eqs. (4.4) and (4.6) and how power is related to σ^2 might be helpful. Because a lossless receiver is assumed, the sum of powers in the I and Q channels must equal the power at the input to the receiver (i.e., the synchronous detectors in Fig. 3.1). Because we have assumed the amplitude of the echo voltage at the receiver's input is A (e.g., Eq. (2.2b)), the amplitude of the signal in the I and Q channels must be $A/\sqrt{2}$. Furthermore, we can determine from Eq. (4.5) that the rms values of the I and Q voltages equals σ (i.e., $I_{\mathrm{rms}} = Q_{\mathrm{rms}} = \sigma$). Thus the average power in each of the channels is σ^2, and the sum of the average powers in these two channels is 2 σ^2 which equals the expected power E[P] at the input to the receivers. The constants of proportionality (i.e., impedances) that relate voltage to power are assumed the same at all points in the receiver (e.g., at inputs to the I and Q channels).

82 0 17 Because there is considerable confusion concerning the use of the unit dBZ, and because some writers use dBz for the decibel unit of reflectivity factor Z, we present the following comment:

The logarithm decibel dB is not an SI unit. On the other hand, the dB has been accepted widely as the symbol of the decibel as a "unit" (e.g., The International Dictionary of Physics and Electronics, D. Van Nostrand Co. Inc., 1961, p.135 of 1355 pp; also Reference Data for Radio Engineers, 5th Edition, Howard W. Sams, publisher, division of ITT, p.3-3 et al.). Furthermore, according to SI rules, units should not be modified by the attachment of a qualifier. Nevertheless, appendages to dB have been accepted in the engineering field to refer the dB unit to a reference level of the parameter being measured; e.g., dBm is the decibel unit for 10 $\log_{10}$ P where P is the power referenced to 1 milliwatt (e.g., Reference Data for Radio Engineers, 5th Edition, p.3-3). dBZ has been accepted by the AMS as the symbol for the "unit" decibel of reflectivity factor referred to 1 $\mathrm{mm}^6\mathrm{m}^{-3}$ (Bulletin, 1987, p.38).

110 at the end of section 5.2, add the following paragraph:

In this section we assumed scatterers follow exactly the air motion. But usually scatterers are hydrometeors that fall in air, have different fall speeds because of their different sizes, and change orientation, and vibrate (if they are liquid). These hydrometeor characteristics broaden the Doppler spectrum associated with the velocity field increasing $\sigma_v^2(\vec{r}_o)$ obtained from Eq. (5.51).

114 2 at the end of this modified paragraph (i.e., see errata) add: "Thus the variance (i.e., the square of the spectrum width) associated with the spectral broadening mechanism due to turbulence can be added to the variances associated with the spectral broadening mechanism due to the steady wind and drop oscillations. Furthermore, steady wind can be expressed as a power series in terms of the displacement of the scatterers from the center of the resolution volume (Section 5.3). Thus the zeroth order term is the radial component of the steady wind *at the resolution volume center*, the first order term gives the spatial dependence of the radial wind due to uniform radial velocity shear (note that uniform wind, uniform in a Cartesian coordinate system, generates radial velocity shear because of the finiteness in the angular width of the beam—Section 5.3), etc. Each term of the power series is part of the sum of velocities in the exponent of Eq. (5.59b), and thus the transform of Eq. (5.59b) can be expressed as a convolution of the spectrum associated with each component of the steady wind. Because the resultant spectrum is a convolution of the spectra associated with each of the mechanisms (i.e., turbulence, shear, etc.) that cause a change of velocity across the resolution volume, the variance (i.e., spectrum width squared) of the resultant spectrum is the sum of the variances associated with the spectra of each mechanism.

118 0 after Eq. (5.75) it should be noted that as $\theta_0 \rightarrow 0$, the angular shears in Eq. (5.74) should be replaced by k_θ along the two principal axes of the beam pattern. For example, if the beam is circular symmetric and $\theta_0 = 0$, $\sigma_s^2 = r_o^2 \sigma_\theta^2 [k_\theta^2(\phi = 0) + k_\theta^2(\phi = \pi/2)] + (\sigma_r k_r)^2$.

After Eq. (5.76): It should be noted that if the receiver bandwidth B_6 is much larger than the reciprocal of the pulse width τ, not an unusual condition, $\sigma_r^2 = \frac{1}{12}\left(\frac{c\tau}{2}\right)^2$.

136 4 1-5 The form of Eq.(6.29) was first presented by Rummler (1968). *But this form does not follow directly from Eq.(6.27) as in stated in the sentences preceding Eq.(6.29).* Thus it would be more proper to change these lines to read:

"If spectra are not Gaussian, Rummler (1968) has derived an estimator valid for small spectrum widths (i.e., $\sigma_{vn} << 1$). This estimator is

(6.29)

At large widths Eq. (6.29) has an asymptotic (M → ∞) negative bias which causes an underestimate of the true spectrum width (Zrnic, 1977b), whereas .... spectrum is Gaussian)"

Added Reference:

Rummler, W. D. (1968), Introduction of a New Estimator for Velocity Spectral Parameters. *Technical Memorandum, April 3, 1968.* Bell Laboratories, Whippany, New Jersey 07981.

195-196 Because we use the terms effective pattern and effective beamwidth, use of the subscript "e" instead of "a" on $f_a(\varphi-\varphi_0)$ and on φ_a would be more natural.

255 1 2 Recent data from a disdrometer show as much as a factor of 3 error

391 0 2 it should be noted that the correlation scale ρ_0 is not the same as the integral scale ρ_I which is defined as

$$\rho_I = \int_0^\infty \frac{R(\rho)}{R(0)} d\rho$$

For the correlation function given by Eq. (10.19), ρ_0 is related to ρ_I as

$$\rho_I = \frac{\Gamma(v+0.5)\Gamma(0.5)}{\Gamma(v)}\rho_0$$

398 Section 10.2.1: we introduce the parameter $\Phi_v(\mathbf{K})$ in Eq.(10.46) but define it later in Eq.(10.46). We should place Eq.(10.48), but label it (10.46), before Eq.(10.46) that now become Eq.(10.47). Other adjustments should be made to correct equation numbers; these should be few.

403 1 6 For a fuller explanation of the steps in Section 10.2.2, and using notation consistent with that used earlier in the text, we offer the following revision of section 10.2.2:

In this section we define the relationship between the variance of radial velocities at a *point* and the expected spectrum width measured by radar (Rogers and Tripp, 1964). Let the variance of the radial velocity $v(\boldsymbol{r}, t)$ at a point be σ_p^2. This variance is the sum of the variance at all velocity scales and is defined by the equation,

$$\sigma_p^2 = E_v[v^2(\boldsymbol{r},t)] - E_v^2[v(\boldsymbol{r},t)] \tag{10.55}$$

where $E_v[x]$ indicates an expectation, or an average over an <u>ensemble of velocity fields</u>, all having the same statistical properties. Assume that steady wind is not present, the radar beam is fixed, and hydrometeors do not oscillate or wobble and are perfect tracers of the wind. In this case, turbulence is the only mechanism contributing to spectral broadening, and it is a random variable having zero mean (i.e., $E_v[v(\boldsymbol{r}, t)] = 0$).

The second central moment, σ_{v}^2, of the Doppler spectrum associated with turbulence can be obtained from Eq. (5.51). Although Eq. (5.51) was derived under the assumption that $v(\boldsymbol{r}, t)$ is steady, this equation can be applied to the time varying wind produced by turbulence. But then σ_{v}^2 would be a time varying quantity because $v(\boldsymbol{r}, t)$ is now a time dependent variable. Replacing subscript 'v' with 't' for pure turbulence, we obtain,

$$\sigma_v^2(t) = \sigma_t^2(t) = \overline{[v(\boldsymbol{r},t) - \overline{v(\boldsymbol{r},t)}]^2} = \overline{v^2(\boldsymbol{r},t)} - \overline{v(\boldsymbol{r},t)}^2 \tag{10.56}$$

where $\overline{\sigma_t^2(\boldsymbol{r},t)}$ is the expected instantaneous second central moment of the Doppler spectrum associated with turbulence. Although $\sigma_v^2(t)$ is a function of $\boldsymbol{r}_0$, the location of the V_6, we have omitted $\boldsymbol{r}_0$ to simplify notation; nevertheless, the argument $\boldsymbol{r}_0$ is implicit in $\sigma_v^2(t)$. The overbar denotes a spatial average weighted by the normalized function $H_n(\boldsymbol{r}_0,\boldsymbol{r})$ where

$$H_n(\boldsymbol{r}_0,\boldsymbol{r}) = \frac{I(\boldsymbol{r}_0,\boldsymbol{r})\eta(\boldsymbol{r})}{\iiint I(\boldsymbol{r}_0,\boldsymbol{r})\eta(\boldsymbol{r})dV}$$

is a combination of reflectivity $\eta(\boldsymbol{r})$ and antenna pattern weights. Because the focus in this section is on the time changing velocity field we assume $\eta(\boldsymbol{r})$ to be time independent.

Note that $\sigma_t^2(t)$ is the <u>expected</u> instantaneous second central moment of the Doppler spectrum. In this case, however, the expectation, $E_\xi[x]$, is over ensembles of scatterer configurations ξ (Doviak and Zrnic, 1993, p.108) each having the same velocity field, whereas the expectation in Eq. (10.55) is taken over ensembles of velocity fields. The, expectations $E_\xi[x]$ can be made, at least in principle, over ensembles of ξ while $\hat{v}(\boldsymbol{r},t_n)$ is frozen. Different scatterer configurations can be obtained by reshuffling scatterer locations. Moreover, although we can in principle freeze the velocity field, scatterers can have differential motion that results in a changing scatterer configuration. This in turn results in changes in the weather signal, and thus fluctuations of the <u>estimates</u> $\hat{\sigma}_t^2(t_n)$ of $\sigma_t^2(t_n)$. The circumflex ^ denotes the estimate made from weather signal samples obtained during a dwell-time, T_d, and 't_n' denotes the n^{th} dwell-time, the short time span of duration MT_s, typically less than 1s. Even though estimate variance associated with different configurations of scatterers is removed by a ξ average, we retain the circumflex '^' to emphasize the estimated value in this section pertains to one member of the ensemble of velocity fields at the n^{th} dwell-time.

The time dependence of $\hat{\sigma}_t^2(t)$ (i.e., of $E_\xi[\hat{\sigma}_t^2(t_n)]$; henceforth the expectation over ξ will not be explicitly shown) is also due to changes of turbulence on scales large compared to V_6 dimensions. Large scales of turbulence are said to create shear across V_6. In this case large scale turbulence contributes a time varying shear component to $\hat{\sigma}_t^2(t)$ that can cause significant fluctuations of $\hat{\sigma}_t^2(t)$. Usually we are not interested in the detailed time dependence of $\hat{\sigma}_t^2(t)$, but in its statistical properties such as its mean or expected value, (i.e., $E_v[\hat{\sigma}_t^2(t_n)]$), its auto-correlation function, etc. In this section we show how $E_v[\hat{\sigma}_t^2(t_n)]$ is related to the energy density $\boldsymbol{E}$ of turbulence.

The $H_n(\mathbf{r})$ weighted radial velocity $\overline{\hat{v}(\mathbf{r},t_n)}$ is defined as the first moment $\hat{v}_m(t_n)$ of the Doppler spectrum estimated from weather signal samples collected during T_d. The variance of $\hat{v}_m(t_n)$ is, by definition, given by

$$\operatorname{var}\left[\hat{v}_m(t_n)\right] \equiv E_v\left[\hat{v}_m^2(t_n)\right] - E_v^2\left[\hat{v}_m(t_n)\right] \equiv \sigma_{\bar{v}}^2(t_n). \tag{10.57a}$$

For pure turbulence, $E_v\left[\hat{v}_m(t_n)\right] = 0$ and thus

$$\sigma_{\bar{v}}^2(t_n) = E_v\left[\hat{v}_m^2(t_n)\right]. \tag{10.57b}$$

Because (10.56) applies to one member of an ensemble of velocity fields, we express (10.56) as

$$\hat{\sigma}_t^2(t) = \overline{[\hat{v}(\mathbf{r},t) - \overline{\hat{v}(\mathbf{r},t)}]^2} = \overline{\hat{v}^2(\mathbf{r},t)} - \overline{\hat{v}(\mathbf{r},t)}^2$$

Where the diacritical simply emphasizes that $\hat{\sigma}_t^2(t)$ is an estimate for one T_d which essentially samples the velocity field. By taking the velocity ensemble average of this equation and substituting Eq. (10.57b) into it, we obtain, after commuting ensemble and spatial averages (i.e., $E_v\left[\overline{v^2(\mathbf{r},t_n)}\right] \equiv \overline{E_v[v^2(\mathbf{r},t_n)]}$),

$$E_v\left[\overline{\hat{\sigma}_t^2(t_n)}\right] + \sigma_{\bar{v}}^2(t_n) = \overline{E_v[\hat{v}^2(\mathbf{r},t_n)]}. \tag{10.58a}$$

The weighted spatial average of $E_v[\hat{v}^2(\mathbf{r},t_n)]$ is, by definition,

$$\overline{E_v[\hat{v}^2(\mathbf{r},t_n)]} = \int_V E_v[\hat{v}^2(\mathbf{r},t_n)] H_n(\mathbf{r}_0,\mathbf{r})\,dV \tag{10.58b}$$

The derivation leading to Eq. (10.58) does not require turbulence to be statistically stationary, homogeneous, or isotropic. That is, Eq. (10.58a) relates the expected value of the second central moment of measured Doppler spectra (i.e., measured estimated with short dwell-times), and the variance of the mean Doppler velocity, to the $H_n(\boldsymbol{r}_0,\boldsymbol{r})$ weighted spatial average of the expected value of the second central moment of the radial component of turbulence at each point ***r*** and t_n. This is in agreement with results of Rogers and Tripp (1964).

These results apply to estimates of the Doppler velocity and second central moments made with any dwell-time. If longer dwell-times are used, $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$ increases because velocity components associated with large scale turbulence have time to evolve within the resolution volume and be adequately sampled. On the other hand, the variance $\sigma_{\bar{v}}^2$ of the mean Doppler velocity decreases as dwell time increases, and it vanishes in the limit of an infinite dwell time. In this limit, $\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}$ solely measures the spatial average of the weighted distribution of turbulence at each point.

10.2.2.1 Estimate variance due to changes in scatterer configuration

It should be noted that the variance, $\sigma_{\bar{v}}^2(t_n)$, does not include the variance associated with the statistical uncertainty due to changing scatterer configurations. Nevertheless, variance (e.g., that discussed in Chapter 6) associated with the weather signal fluctuations due to changes in the scatterer configuration can be significant, and it needs to be included in any rigorous analysis of radar measurements of turbulence.

For example, in addition to the variance of $\overline{\hat{v}(\boldsymbol{r},t_n)}$ due to the time changing velocity field, we have additional variance associated with the random location of scatterers (i.e., the time dependence of the true $\overline{\hat{v}(\boldsymbol{r},t_n)}$ differs from the time dependent $\overline{\hat{v}(\boldsymbol{r},t_n)_R}$ estimated with radar). Here $\overline{\hat{v}(\boldsymbol{r},t_n)}$ is the weighted velocity irrespective of the scatterer configuration.

Even if $\hat{v}(\boldsymbol{r},t_n)$ was a constant independent of time, the radar estimates $\overline{\hat{v}(\boldsymbol{r},t_n)_R}$ would be fluctuating due to the fact that scatterers move continuously to new locations for the same velocity field. That is, there is an evolving configuration of scatterers, and each configuration of scatterers produces a different weather signal sample from which $\overline{\hat{v}(\boldsymbol{r},t_n)}$ is estimated. In general, time fluctuations of estimates are due to both a changing velocity field and a changing configuration of scatterers.

To illustrate, assume a constant wind that carries scatterers along range arcs. In this case, the radial velocity field $\overline{\hat{v}(\mathbf{r},t_n)} = 0$. Nevertheless, radar estimates of $\overline{\hat{v}(\mathbf{r},t_n)}$ are time varying and random; this is so because the scatterers' configuration within V_6 continually changes as new scatterers enter V_6, and others leave it. That is, the In-phase, *I*, and Quadrature, *Q,* components of the weather signal are still Gaussian distributed random variables as shown in Fig. 4.4a. In other words, although the mean or expected Doppler velocity is zero, the time sequence of the *I, Q*, samples will randomly move in the *I, Q* plane, and Doppler velocity estimates made with a small number of samples (e.g., two) can have non zero values.

The changes of *I, Q* from sample pair to sample pair can be relatively small if the sample pair spacing is short compared to the correlation time τ_c of the weather signals, and if the intra-pulse spacing $T_s << \tau_c$. The weather signal correlation time τ_c, approximately equal to the time required to flush V_6 with new scatterers, is not necessarily equal to the correlation time of the velocity field; in our simple illustration the correlation time of the velocity field is infinite. The non zero velocity estimates, calculated from pairs of *I, Q* samples, are uncorrelated if the pair spacing is longer than τ_c. Only with a long time average will these velocity estimates average to 0.

These arguments, applied to the radar estimates of $\overline{\hat{v}(\mathbf{r},t_n)}$, can also be applied to show that the ξ expectation of the radar estimates $\overline{\hat{\sigma}_t^2(\mathbf{r},t_n)_R}$ {i.e., $E_\xi\left[\overline{\hat{\sigma}_t^2(\mathbf{r},t_n)_R}\right]$} equals $\overline{\hat{\sigma}_t^2(\mathbf{r},t_n)}$.

10.2.2.2 Homogeneous turbulence

If turbulence is homogeneous over the region where the weighting functions contribute significantly (i.e., turbulence is locally homogeneous), Eq. (10.58b) shows that $\overline{E_v[\hat{v}^2(\mathbf{r},t_n)]} = \sigma_p^2(t_n)$, the "point-measured variance" (Frisch and Clifford, 1974; the following paragraph will clarify what is meant by "point-measured variance"). The radial component of the turbulent energy density at a point is, $E_r = \frac{1}{2}\gamma\sigma_p^2$, where γ is the air mass density. Using Eq. (10.58a), and noting that $\overline{E_v[\hat{v}^2(\mathbf{r},t_n)]} = \sigma_p^2(t_n)$, we can then relate E_r to radar measurements as

$$E_r = \frac{1}{2}\gamma\sigma_p^2(t_n) = \frac{\gamma}{2}\left\{E_v\left[\overline{\hat{\sigma}_t^2(\mathbf{r},t_n)}\right] + \sigma_{\bar{v}}^2(t_n)\right\}. \qquad (10.59)$$

If turbulence is isotropic, the total turbulence energy density $E = 3E_r$.

Eq. (10.59), establishes a relation between the radial component of the "point-measured" turbulent energy density and the second central moment of the Doppler spectrum associated with turbulence, but it requires turbulence to be *locally* homogeneous although not isotropic or stationary. Therefore, the "point" under discussion is, in reality, a collection of points over the entire resolution volume wherein turbulence is assumed to have the same statistical properties at each point. Section 10.2.2.3 presents results for the case where turbulence is inhomogeneous.

Eq. (10.59) demonstrates that the energy density of the radial component of "point-measured" homogeneous turbulence can be calculated from the sum of the expected value of the second central moment, $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$, and the variance, $\sigma_{\bar{v}}^2 = E_v\left[\overline{\hat{v}(\boldsymbol{r},t_n)}^2\right]$, of the mean Doppler velocity estimates. It also shows how that energy is partitioned between large and small scales of turbulence; $\sigma_{\bar{v}}^2$ is principally due to large scale turbulence whereas $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$ is principally due to small scale turbulence.

If the radial component of turbulence has a -5/3rds power law vs wavenumber $K = 2\pi/\Lambda$ for all wavelengths Λ of the spectrum of turbulence, and if the dimensions of V_6 are the same in all directions (i.e., $\sigma_\theta r_o = \sigma_\phi(\theta_0) r_o = \sigma_r$; section 5.3), it can be shown that turbulence from all $\Lambda \le L_c \equiv \sigma_\theta r_o$, the characteristic size of V_6, contributes only about 20% to $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$. Thus, although some portion of $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$ is due to small scales, most of its contribution comes from turbulence on wavelengths large compared to L_c; this appears at variance with previously published interpretations. For example, if the weighting function is uniform, as stipulated by Rogers and Tripp (1964), across V_6 having dimensions $LxLxL$, only 36% of $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$ is due to turbulence from all $\Lambda \le L$. This contradicts Rogers and Tripp (1964) statement that $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$ "receives spectral contributions mainly from the wavelengths shorter than the dimensions of V_6".

Large scale (i.e., large compared to V_6 dimensions) turbulence shifts the Doppler spectrum along the velocity axis so that the single spectrum mean Doppler velocity changes from one spectrum to the next. Thus to estimate $E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right]$ we need to average the second central moments calculated about each of the fluctuating means. For stationary and/or globally homogeneous turbulence, expectations can be obtained from averages over time and/or space (i.e., at different $\boldsymbol{r}_0$ locations).

10.2.2.3 Inhomogeneous turbulence

It is not necessary to assume turbulence is homogeneous (as we did in arriving at Eq. 10.59) to obtain a relation between the point variance of the radial component of turbulence and radar measurements. If turbulence is not homogeneous, $\sigma_p^2(\boldsymbol{r},t_n)$ is still the variance at a point $\boldsymbol{r}$, but $\overline{\sigma_p^2(\boldsymbol{r},t_n)}$ is the $H_n(\boldsymbol{r}_0,\boldsymbol{r})$ weighted spatial average wind variance at each point. Then the expression for the point variance must be written as,

$$\overline{\sigma_p^2(\boldsymbol{r},t_n)} = E_v\left[\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}\right] + \sigma_{\bar{v}}^2(t_n)\,.$$

This is exactly the same form as Eq. (10.59), but we now have an overbar on $\sigma_p^2(\boldsymbol{r},t_n)$. This simply means that radar can only measure the $\underline{H_n(\boldsymbol{r}_0,\boldsymbol{r})}$ weighted spatial average of turbulence at each and every point.

As stated earlier (section 10.2.2.1), the variance $\sigma_{\bar{v}}^2$ does not include the variance associated with the statistical uncertainty of the estimates of $\overline{v(\boldsymbol{r},t)}$ due to weather signal fluctuations (i.e., the variance associated with changes in the scatterers' configuration). The variance associated with the statistical uncertainty of the estimates must be subtracted from the measured variance in order to obtain $\sigma_{\bar{v}}^2$; window biases, typically associated with the measurements of $\overline{\hat{\sigma}_t^2(\boldsymbol{r},t_n)}$ (Doviak and Zrnic, 1984, Fig. 6.8; Melnikov and Doviak, 2002), must also be taken into account.

439 0 9 because section 11.4.1 is titled "Bragg scatter", it is appropriate to define and use this term in this section. Therefore change this line to read: ".. to the scattered signal (i.e., Bragg scatter) occurs if.."

443 section 11.4.3 to differentiate the commonly known Bragg scatter associated with steady or deterministic perturbations from that Bragg scatter associated with random perturbations, we introduce the term "Stochastic Bragg Scatter" by replacing the second sentence of this section with:

"Perturbations in atmospheric refractive index are caused by temperature and humidity fluctuations; thus the perturbation in *n* is a random variable having a spectrum of scales. Although there is a spectrum of spatial scales, only those at about the Bragg wavelength $\Lambda_B = \lambda/[2\sin(\theta_s/2)]$ contribute significantly to the backscattered power. Because scatter is from spatial fluctuations in refractive index, the scattering mechanism is herein defined as Stochastic Bragg Scatter (SBS). Because there are temporal fluctuations as well, the scattered power is also a random variable and its properties are related to the statistical properties of the scattering medium. In this section we relate the expected…..(return to the 3rd sentence in the text)"

459 Eq. (11.124) this equation assumes that the beam width is given by Eq. (3.2b). A more general form is

$$\rho_\perp = \frac{D_a\sqrt{2}}{\pi\gamma_1}, \qquad \theta_1 = \gamma_1\frac{\lambda}{D_a}$$

	4		at the end of this paragraph, “...in this section.”, add: “Under far field conditions the beamwidth part of the “resolution volume weighting” term in Eq.(11.122) does not contribute significantly to the integral, but beamwidth and range resolution do contribute to the backscattered power because they multiply the integral in Eq.(11.122).”
460	0	2	add the following sentence at the end of the line: ρ_h is the outer scale of the refractive index irregularities, but condition (11.124) applies to the transverse correlation lengths of the Bragg scatterers. Thus, the conclusion reached in this paragraph applies if the Bragg scatterer's correlation length equals the outer scale.
461	0	11	insert after "...in space.": "This is a consequence of the greater importance of the Fresnel term relative to the resolution volume weighting term (i.e., in Eq.11.122) along the transverse directions."
478	0	7	rewrite the sentence: “Then *g*, now the directional gain (section 3.1.2) is related to…”
513	3	4	rewrite as: “…independent of all others because the shell is assumed to be many wavelengths thick and scatterers are randomly placed in the shell.
547	Index		add: “Antenna; far field, 435-436, 459”
548	Index		add: “Bright band, pp. 256, 268”
554	Index		add “Melting layer, pp. 225, 255”
556	Index		for the entry “Radome losses” add page 43.