

الاتحاد الدولي للاتصالات

ITU-R

قطاع الاتصالات الراديوية في الاتحاد الدولي للاتصالات

ITU-R P.531-11

(2012/02)

P



(IPR)

(ITU-T/ITU-R/ISO/IEC)

.ITU-R 1 1

<http://www.itu.int/ITU-R/go/patents/en>

http://www.itu.int/publ/R-REC/en)	
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		BO
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	<i>.ITU-R 1</i>

ITU-R P.531-11

(ITU-R 218/3)

(2012-2009-2007-2005-2003-2001-1999-1997-1994-1992-1990-1978)

	-	ITU-R P.531	
:	-	.GHz 12 0,1	-
		()	-
	(TEC)		-
		()	-
	.		-
		.1	
	GHz 12		(
GHz 3		/	(
			(
			(
	1		1

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(MSS)

MSS

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(TEC)

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MSS

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GHz 3

MSS

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MSS

MSS

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2

(TEC)

F E D

(TEC)

TEC

(TEC)

1.3

:

N_T

TEC

(1)

$$N_T = \int_s n_e(s) ds$$

:

(m)

ds

(el/m^3)

n_e

n_e

N_T

m^{-2}

TEC

$\text{el}/\text{m}^2 \cdot 10^{18}$

(TEC)

(IRI-2007 v.P531-11) (IRI)

TEC

.NeQuick2 v.P531-11

TEC

(IRI-2007)

1.1.3

(COSPAR-URSI

) IRI-95

.(IRI-2007 v.531-11)

.km 2 000

.IRI-2007

.km 300

NeQuick2

2.1.3

)

(F2

)

:

.(ITU-R P.1239

) foF2/foE

M(3000)F2

F2

.(F2

F

.F2 F1 E

NeQuick2 v.P531-11

- -

θ

:

(2)

$$\theta = 2.36 \times 10^{-14} \frac{B_{av} N_T}{f^2}$$

:

(rad) : θ

(Teslas Wb · m⁻²) : B_{av}

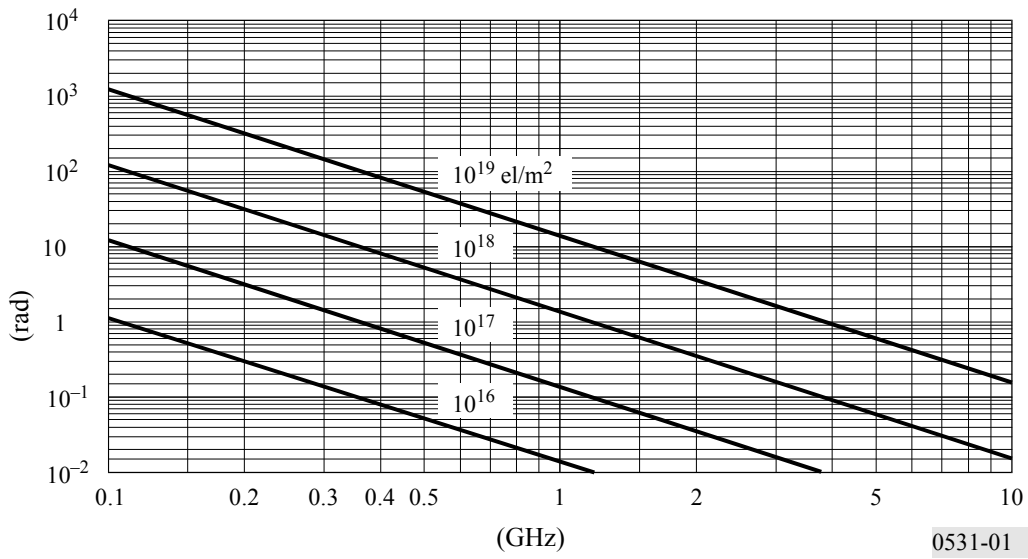
(GHz) : f

(electrons · m⁻²) TEC : N_T

θ 1

1

TEC



0531-01

: θ XPD (dB)

(3) $XPD = -20 \log (\tan \theta)$

3.3

: t

.MSS

(4) $t = 1.345 N_T / f^2 \times 10^{-7}$

:

(s) :t

(Hz) :f

:N_T

f t 2

ns 500 0,5

MHz 1 600

3 .el²/m¹⁹10¹⁶10

ns 20

4.3

()

μs 1

el²/m¹⁷10 × 5

4

.(4) μu 0,00074

MHz 600

MHz 200

μs 0,02

TEC

5.3

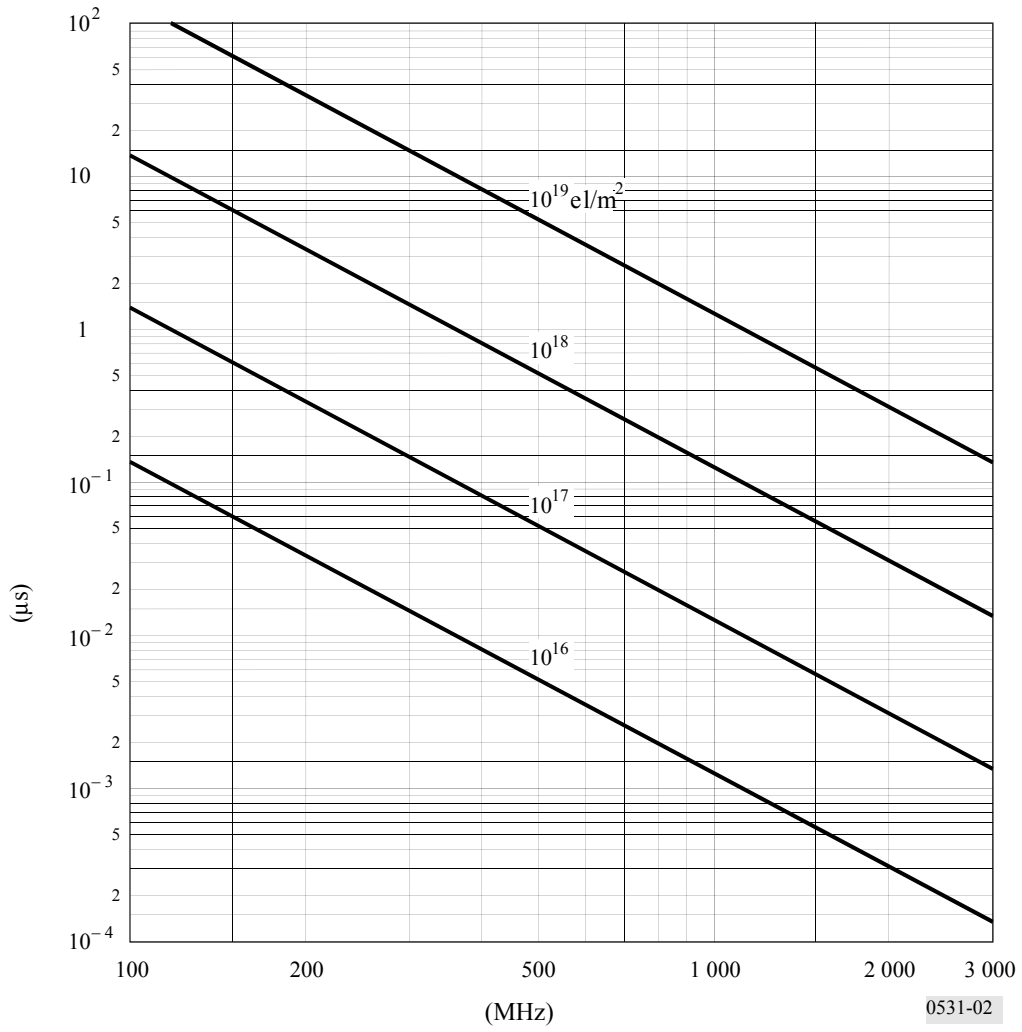
TEC

km 22 000

.m/s 0,11

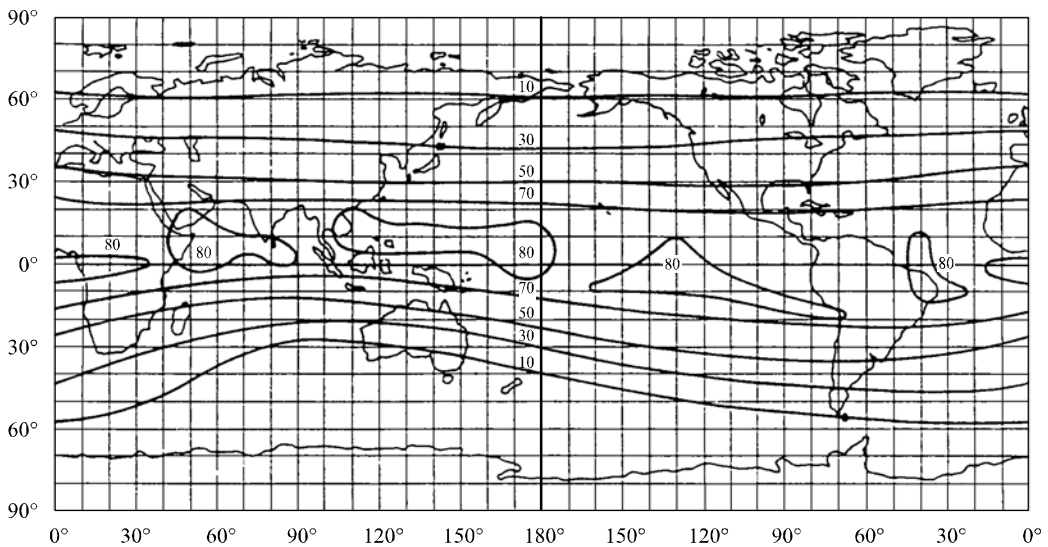
.el²/m/s¹⁶10 × 0,7

2

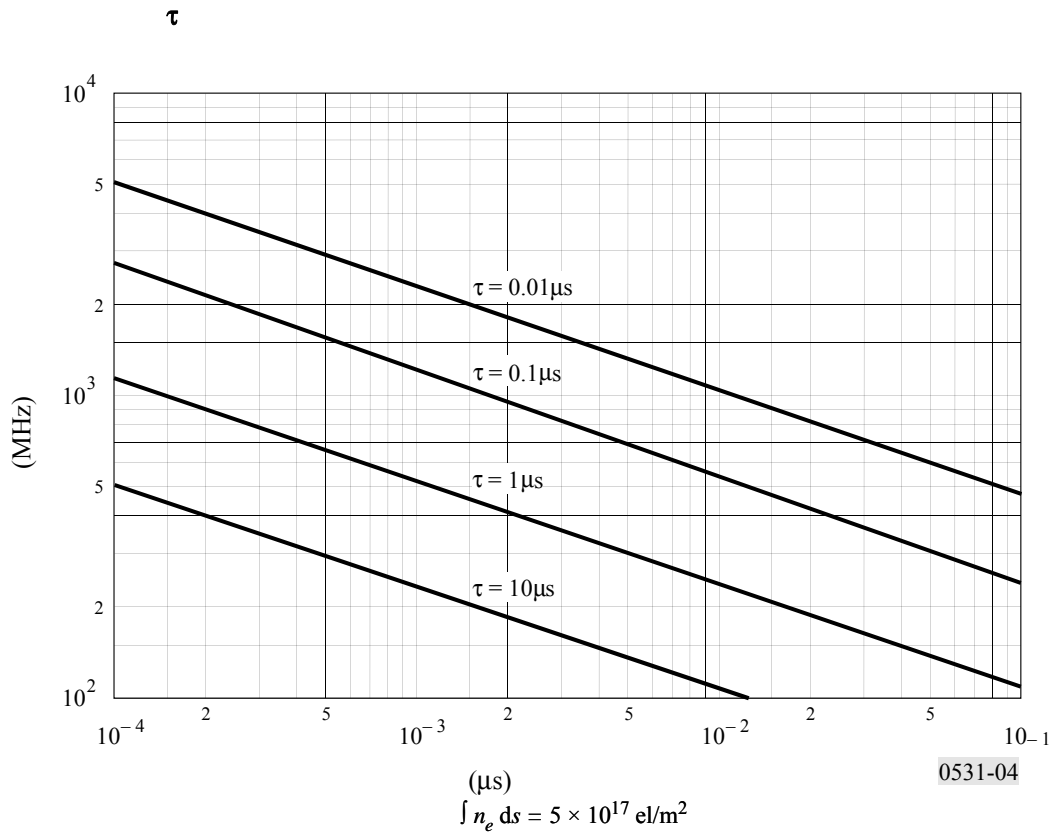


3

(140 =) ns 20 GHz 1,6



4



4

1.4

.GHz 10

.GHz 3

:(5)

S_4

(5)

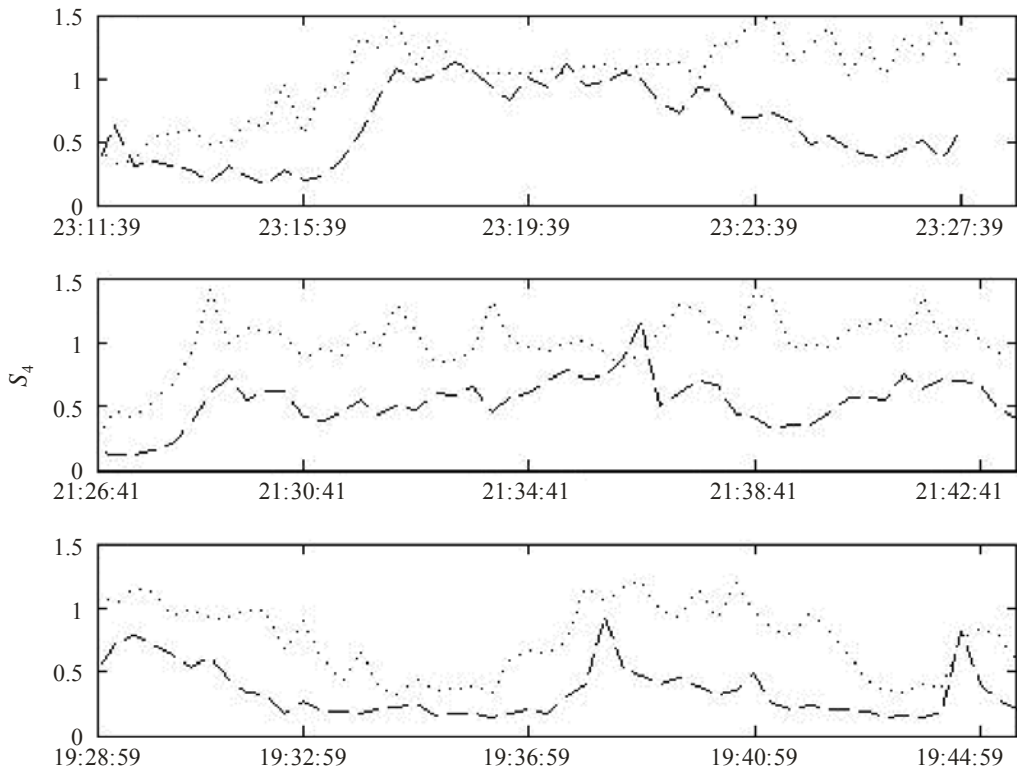
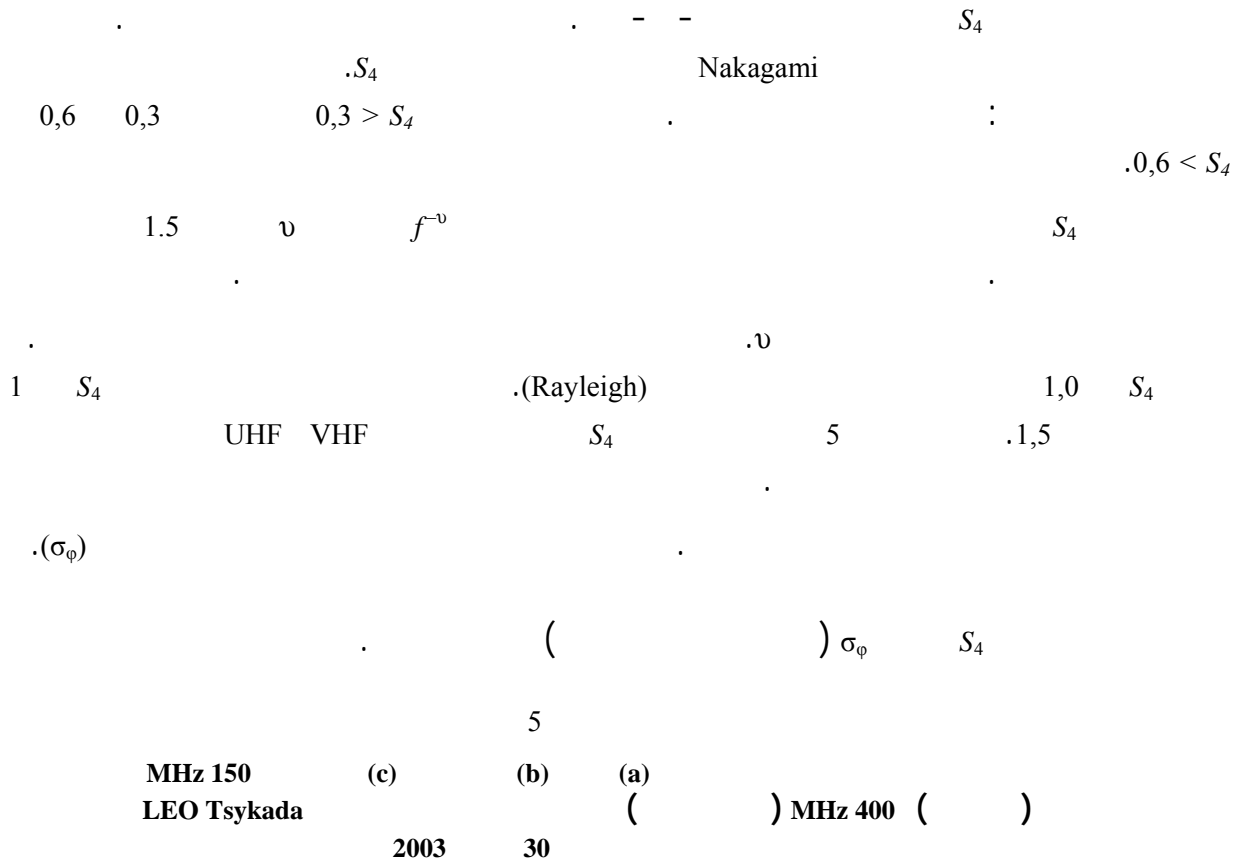
$$S_4 = \left(\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2} \right)^{1/2}$$

$\langle \rangle$

(

)

I



UT

P_{fluc} - - S_4 1
 : .(dB)

(6)
$$P_{fluc} = 27,5 S_4^{1,26}$$

 1

P_{fluc} (dB)	S_4
1,5	0,1
3,5	0,2
6	0,3
8,5	0,4
11	0,5
14	0,6
17	0,7
20	0,8
24	0,9
27,5	1,0

2.4

$\pm 20^\circ$:

.7 6

.dB 10 GHz 4

3.4

S_4 .(GISM v.P531-11) (GISM)

·
 :

3 = p -

km 500 = L_0 -

.0,2 = σ_{Ne} -

GISM v.P531-11

.NeQuick2 v.P531-11

3

4.4

1.4.4

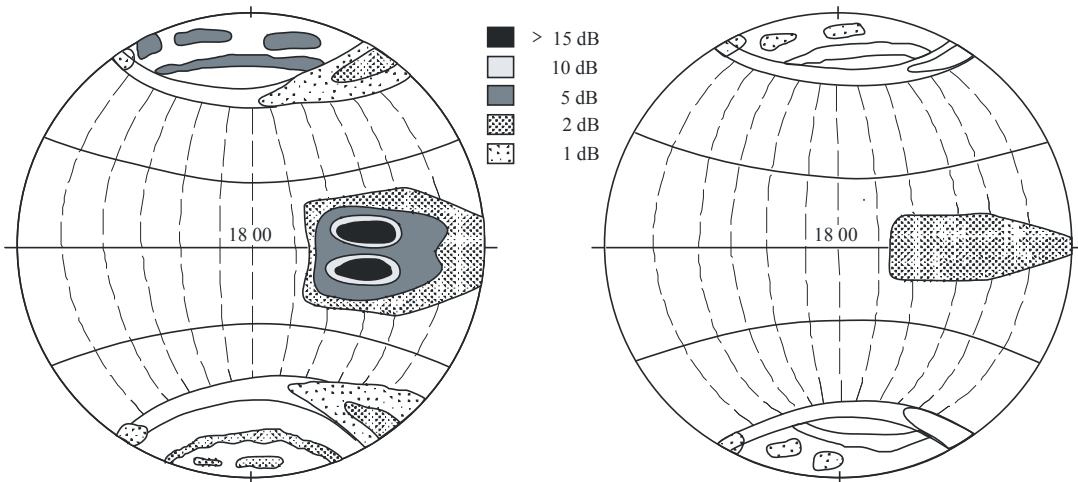
Nakagami

:

(7)
$$p(I) = \frac{m^m}{\Gamma(m)} I^{m-1} \exp(-mI)$$

6

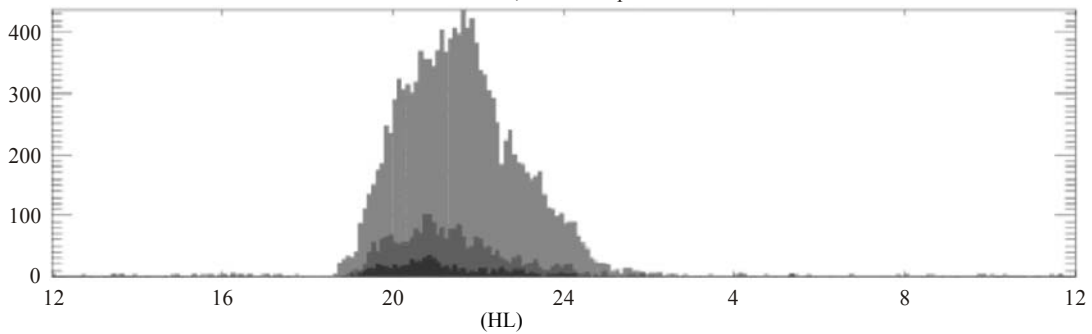
GHz 1,5 ()



0531-06

7

S_4
 $20 <$
 () () ()
 (0,55 <) (0,55 0 0,4) (0,4-0,25) : S_4
 $20 <$



0531-07

(8)
$$m = 1/S_4^2$$
 Nakagami "m"
$$P(I) = \int_0^I p(x) dx = \frac{\Gamma(m, mI)}{\Gamma(m)}$$
 Nakagami
$$P(10^{-X/10}) = 1 - P(10^{Y/10})$$

(9)
$$P(I) = \int_0^I p(x) dx = \frac{\Gamma(m, mI)}{\Gamma(m)}$$

$$P(10^{-X/10}) \text{ dB X}$$

$$1 - P(10^{Y/10}) \text{ dB Y}$$

2.4.4

8 Hz 1 0,1 $6-f$ $1-f$ $3-f$

5.4

1.5.4

$$S_4 \propto \exp\left[-\frac{\beta}{W}\right]$$

$$S_4 \propto \exp\left[-\frac{\beta}{W}\right]$$

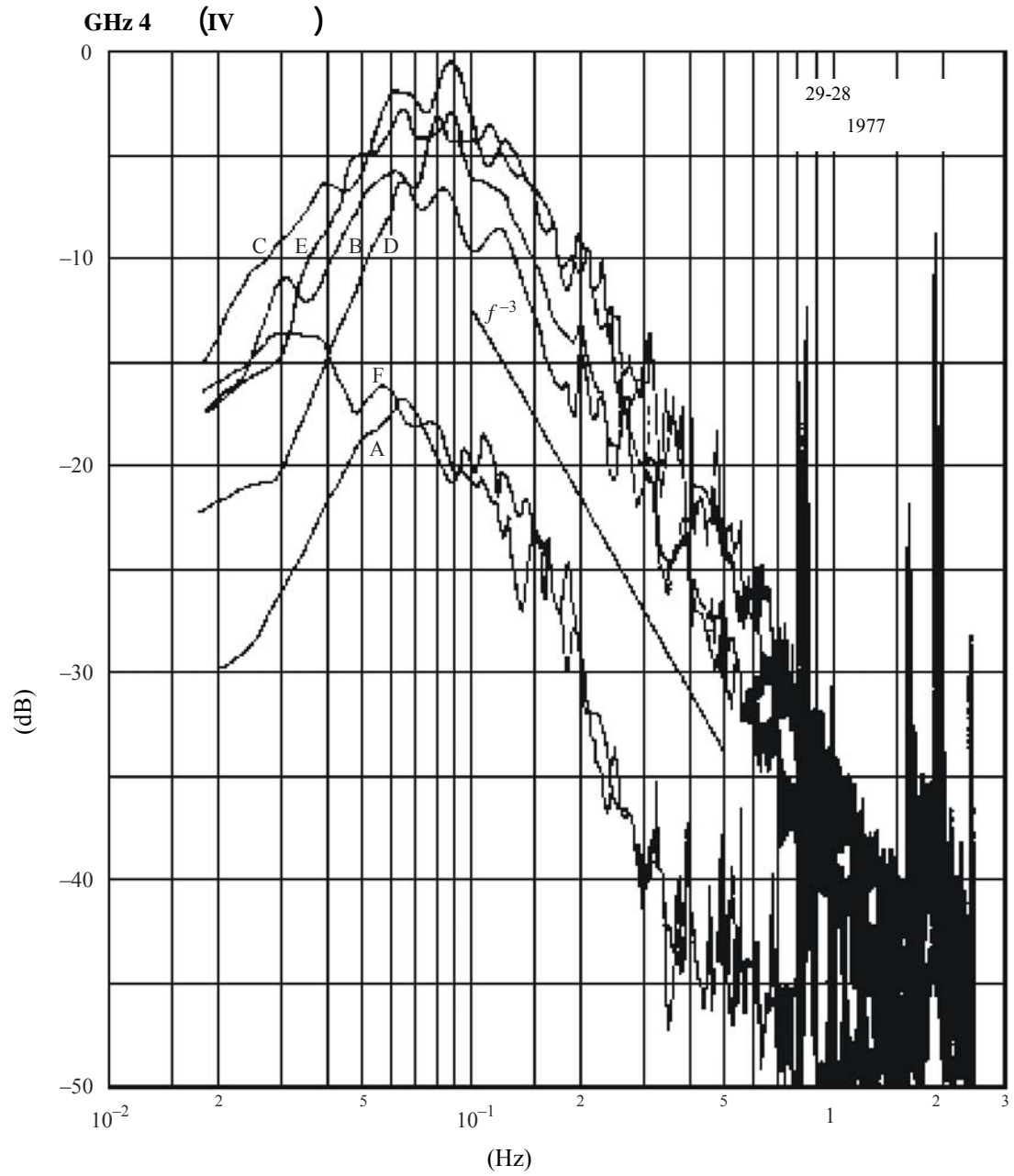
2.5.4

9b β S_4

(10)
$$S_4 \propto \exp\left[-\frac{\beta}{W}\right]$$

$$S_4 \propto \exp\left[-\frac{\beta}{W}\right]$$

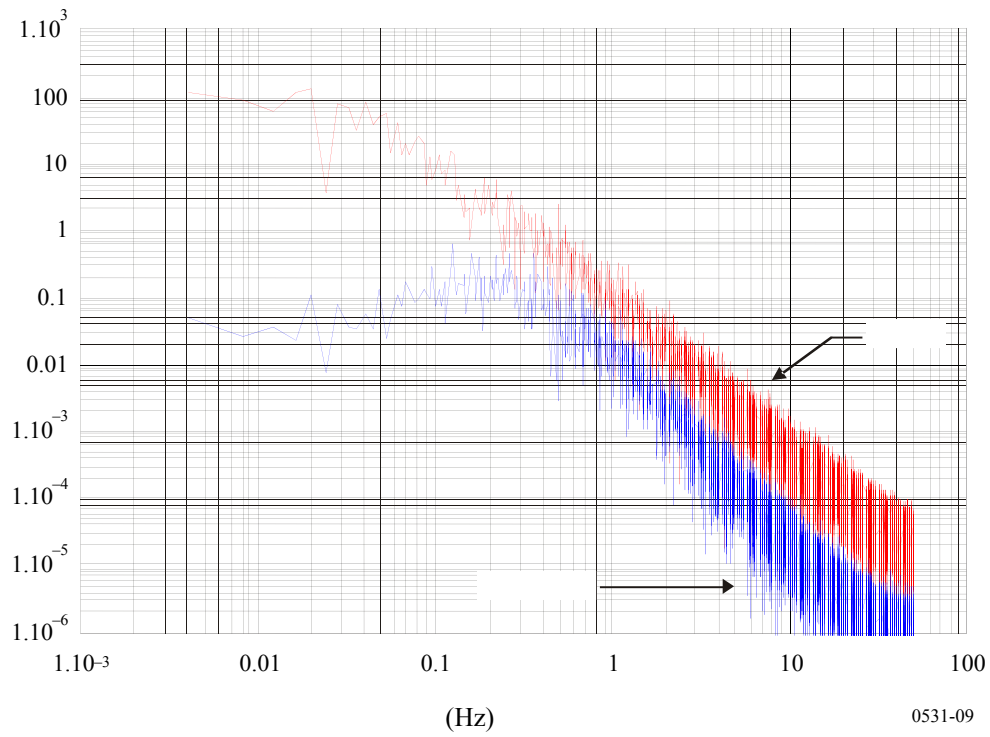
8



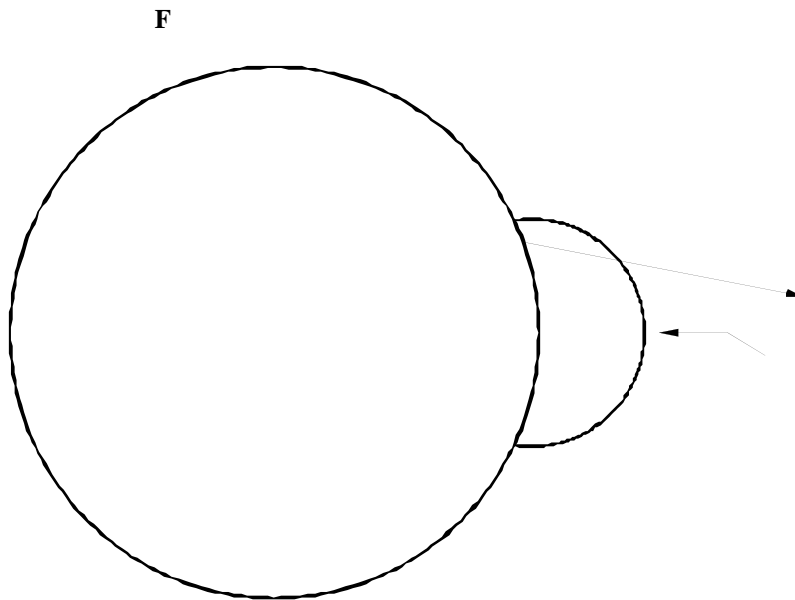
1977 29 28

30 :A
:B
:C
:D
:E
:F

P0531-08



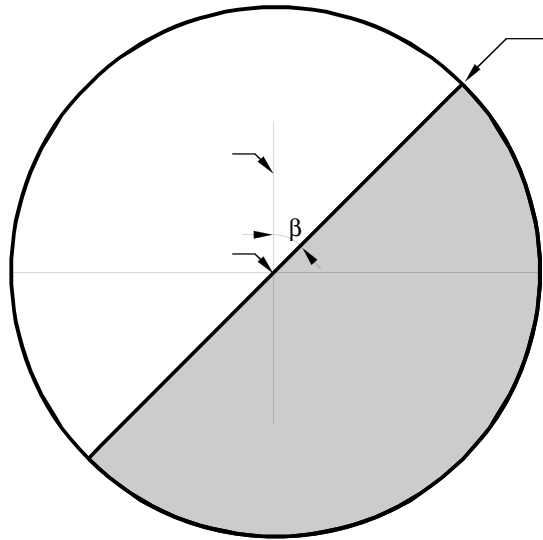
9a



0531-09a

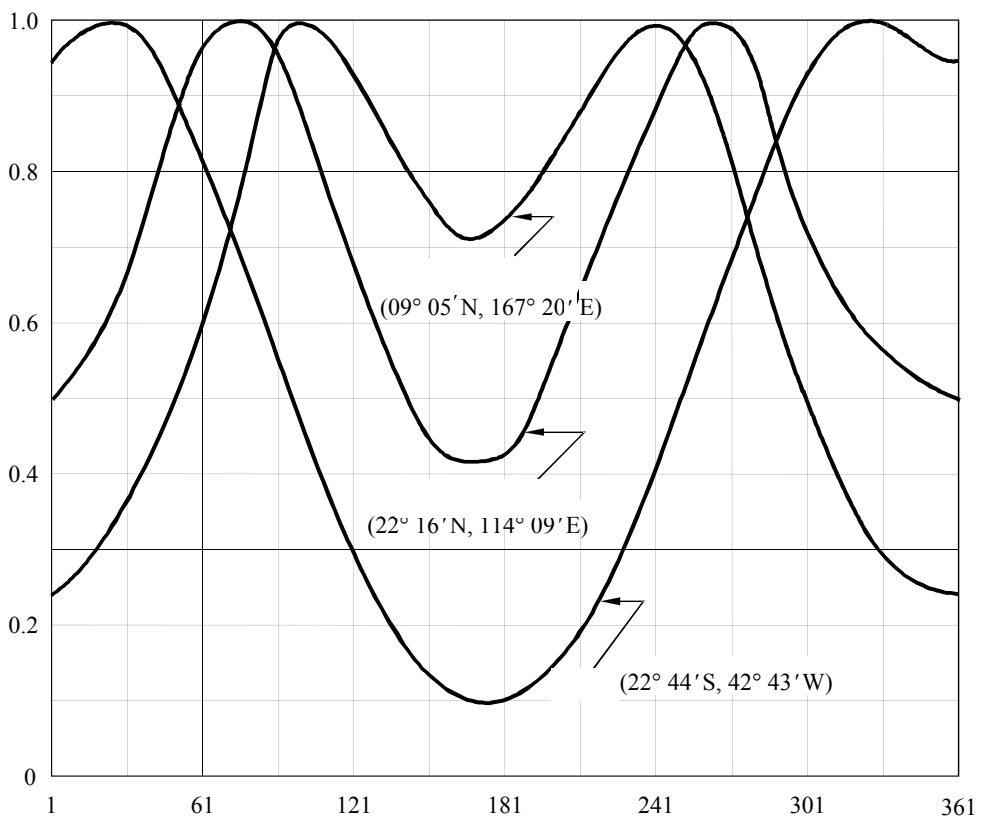
9b

9a



0531-09b

10



0531-10

11

12

12

$$P(I) = \int_{\xi} F(\xi)$$

(11)
$$P(I) = \sum_{i=0}^n f_i P_i(I)$$

(11a)
$$f_0 = F(\xi < \xi_1)$$

(11b)
$$f_i = F(\xi_i \leq \xi < \xi_{i+1}) \quad (i = 1, 2, \dots, n-1)$$

(11c)
$$f_n = F(\xi \geq \xi_n)$$

ξ n ξ_n ξ_1

(11d)
$$P_i(I) = \Gamma(m_i, m_i I) / \Gamma(m_i)$$

(11e)
$$m_i = 1/S_{4i}^2$$

(11f)
$$S_{40} = \left[\frac{1}{27.5} \cdot \frac{\xi_1}{2} \right]^{1/1.26}$$

(11g)
$$S_{4i} = \left[\frac{1}{27.5} \cdot \frac{\xi_i + \xi_{i+1}}{2} \right]^{1/1.26} \quad (i = 1, 2, \dots, n-1)$$

(11h)
$$S_{4n} = \left[\frac{1}{27.5} \cdot \frac{\xi_{n-1} + 3\xi_n}{4} \right]^{1/1.26}$$

.11 P6

12

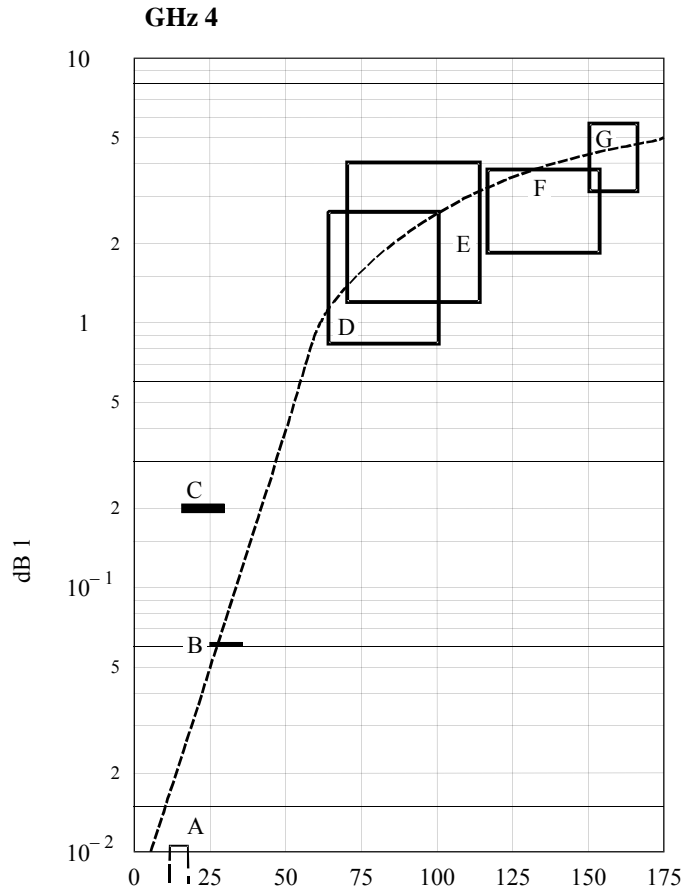
%0,06

GHz 4

()

.ITU-R P.618

11



	15	1976-1975	:A
		1974	:B
		1977-1976	:C
	50 <	12 1971-1970	:D
	12	1978-1977	:E
	10	1979-1978	:F
0531-11	6	1980-1979	:G

GHz

8.4

:

(dB) P_{fluc} : 12 :/

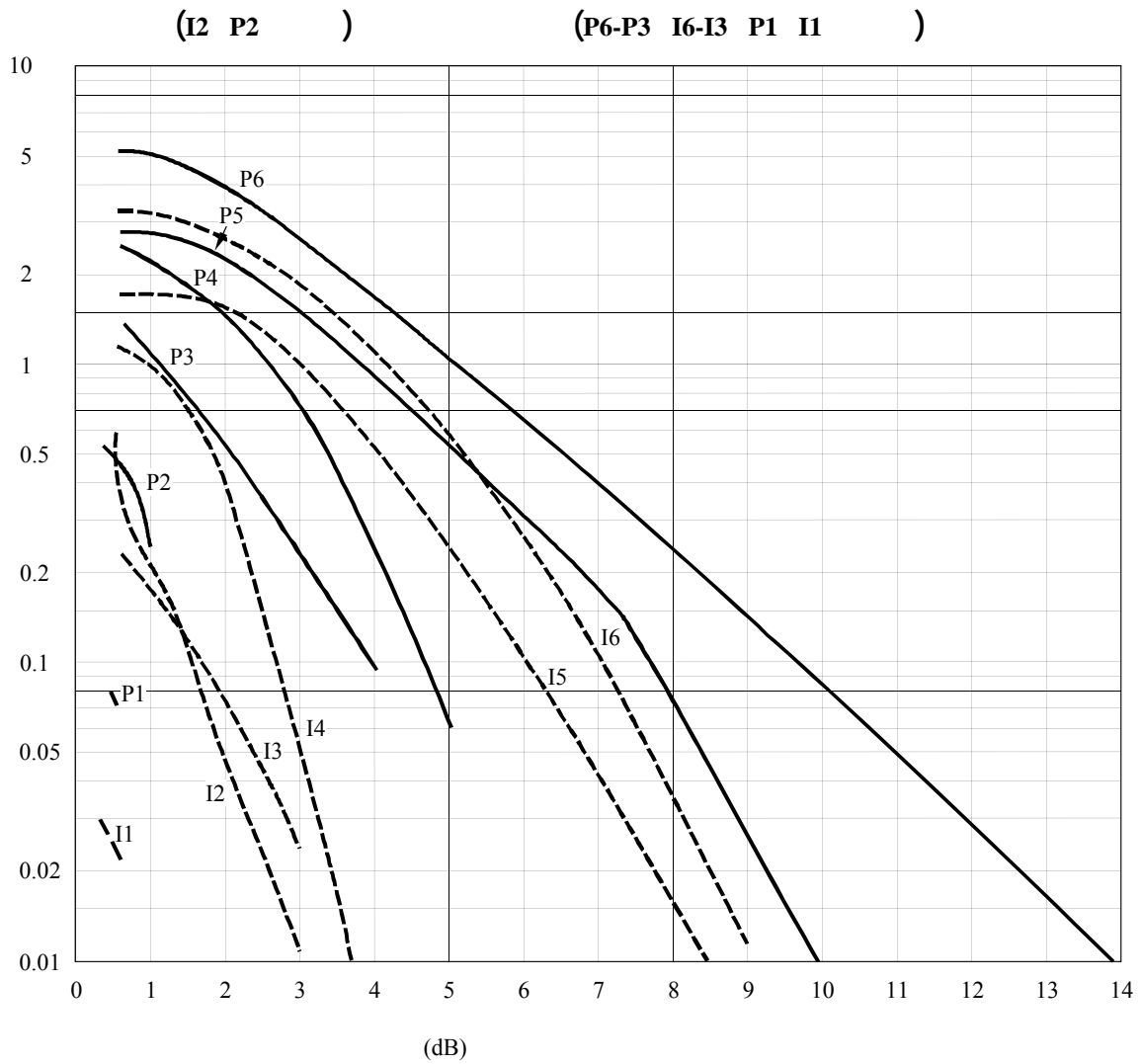
(P) °20 GHz 4

.(I) °30

GHz 4 12 :2

.(GHz) f $1.5-(4/f)$

12



15-10	76-75	P1 I1
26-12	77-76	P2 I2
70-20	78-77	P3 I3
110-44	78-77	P4 I4
160-110	79-78	P5 I5
165-153	80-79	P6 I6

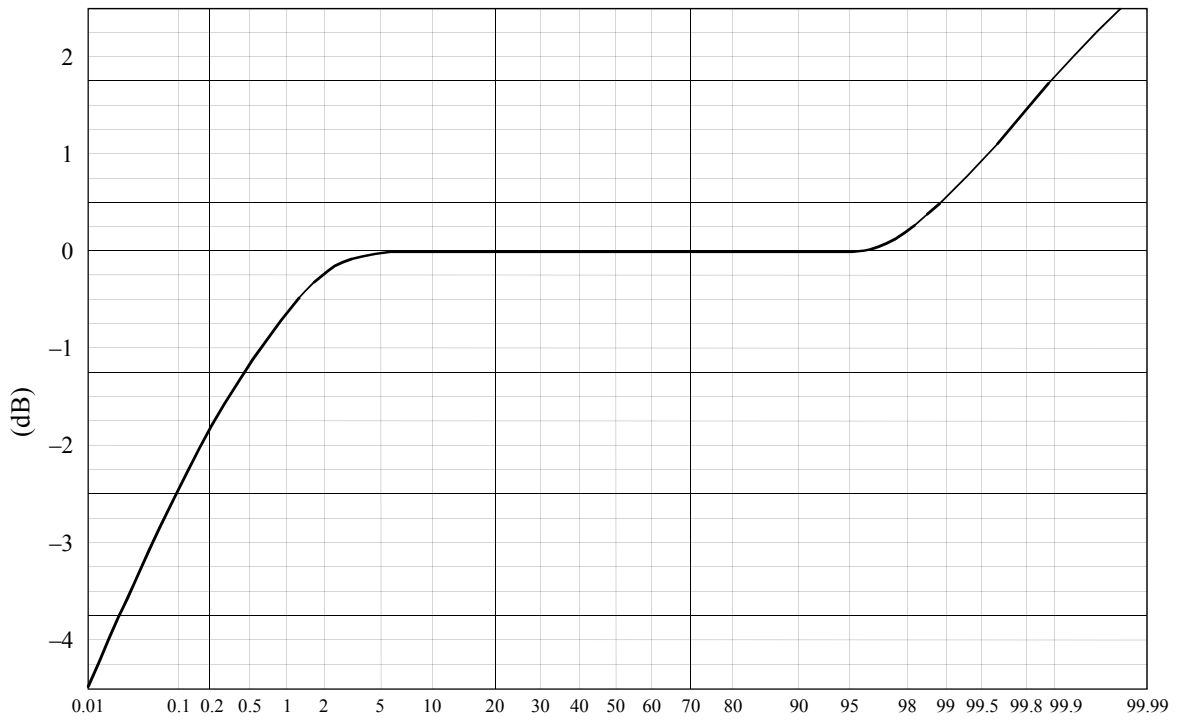
$$L_p = P_{fluc} / \sqrt{2}$$

$$S_4 = 1.4$$

$$.1 P_{fluc}$$

13

(20 GHz 4)



0531-13

5

i MHz 30

²*f*/(sec *i*)

MHz 70

MHz 30

.dB 0,5 0,2

.dB 5

E D

°20 °10

30

.MHz 127

2

2

(dB) MHz 127

°5	°20	
2,9	1,5	0,1
1,7	0,9	1
1,4	0,7	2
1,1	0,6	5
0,4	0,2	50

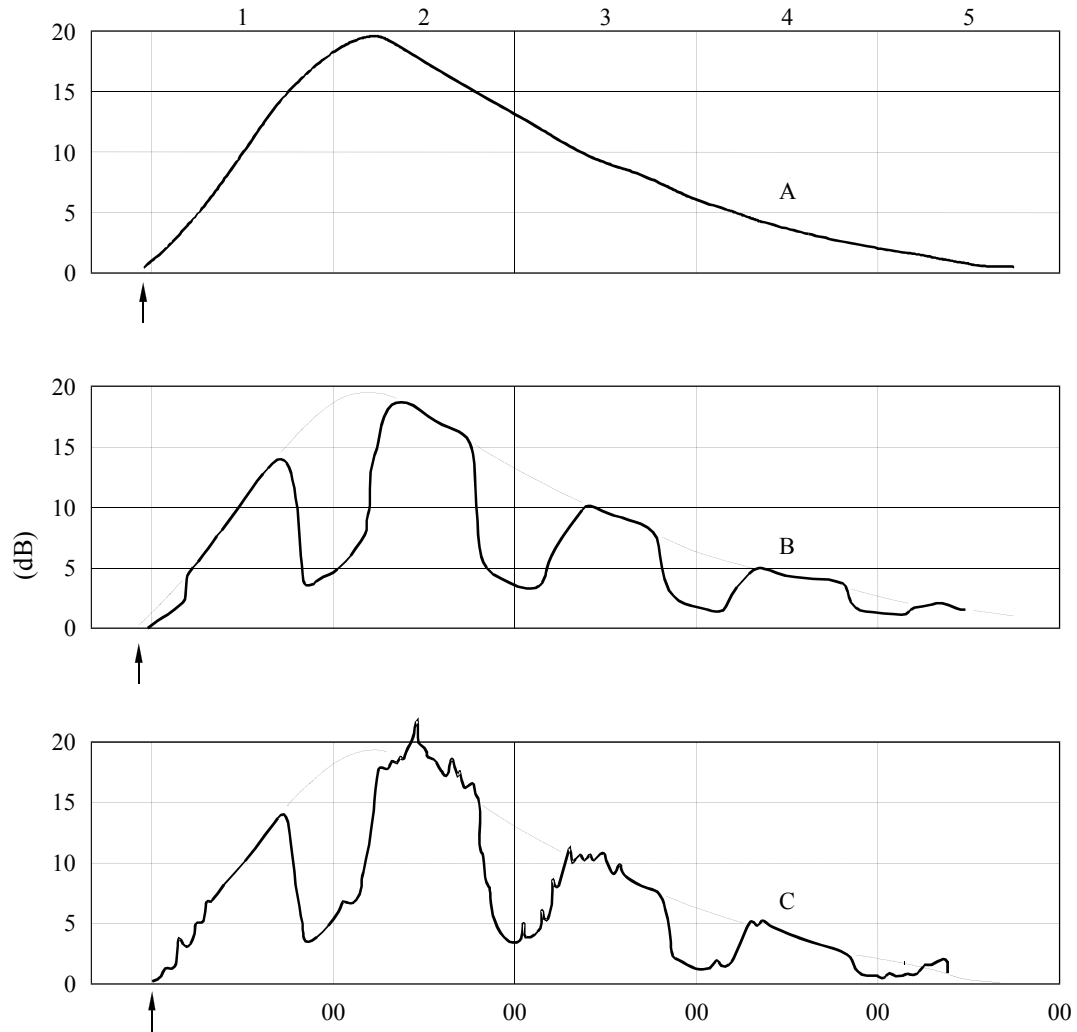
km 30

.°64

12 10

14

MHz 30



24 - :A 0531-14
 - :B
 - :C

.GHz 1 3
 .°30 .el²/m¹⁸10

3

GHz 1

°30

$1/f^2$	°108	
$1/f^2$	μs 0,25	
$1/f^2$	mrad 0,17 >	
$1/f^2$	0,2	
$\sim 1/f^2$	dB 0,04	()
$\sim 1/f^2$	dB 0,05	(+)
$1/f^2$	dB 0,01 >	()
$1/f^3$	ns/MHz 4-0	
4	4	