Project: ADSL

Title: Proposal for Parametric ADSL Cable Models

Source: FTW

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Abstract:

This paper suggests the use of parametric cable models instead of the primary cable parameter tables currently in use.

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1. Introduction

Annex A of the ADSL draft specification [1] contains tables of primary parameters for various cables. These primary parameters are then used to generate test loops. Currently the tables specify the primary parameters RLC from dc to 1100 kHz, with the capacitance C held constant for the whole frequency range.

As already partly pointed out in TD27 [5] this way of defining the cable characteristics has some drawbacks:

- It is not specified how to interpolate and thus there is room for different interpretations when cable parameter values at intermediate frequencies are needed.
- Another problem arises because the downstream ADSL band extends to 1104 kHz, which means the tables could be considered incomplete.
- Furthermore, if for any reason (i.e., accurate modeling of the channel and noise in time-domain system simulations) the primary parameter values above the ADSL band are required, extrapolation from the given values is necessary.
- The extrapolation process may not always result in correct insertion loss values above the band edge, which could in turn jeopardize the quality of simulation results. Note that using cubic splines in the standard interpolation method in matlab has changed its behavior (especially with regard to extrapolation) in between version 5 and 6!
- As noted in [3,4] these parameters will result in no-causal time domain behavior.

It is possible to address these problems in many ways:

1. Ignore it and let everyone interpret it at intermediate and extended points to their benefit
2. Add a few points at higher frequencies (as suggested in TD27)
3. Define a (normative) parametric model that gives RLCG values as close as possible to the tables given in Appendix A (a BT parametric model)
4. Define a (normative) parametric model that matches the tables as well as possible but have realistic (causal) time-domain behavior (a MAR model)

We suggest that the fourth way of addressing the problem be used. In the next section we establish some parametric models and compare them to the current tables.

2. Analysis

The note in Annex A indicate that the RLC table values should be the same as in ITU-T recommendation G.996.1 [2] and as a parametric (BT) model is given there we can assume that there exists a BT model parameter set that exactly generates these RLC tables. However, the parameters stated in [2] do not give exactly the tables we have in Annex A (probably due to sloppy rounding of the parameters). In fact have we found that the parameter set given in [3] gives a better fit.

The BT model

The equations for the BT model is [6,7]:

$$Z_0 = \left(\frac{1}{\sqrt[4]{R_{oc}^4 + a_c f^2}} + \frac{1}{\sqrt[4]{R_{os}^4 + a_s f^2}} \right)^{-1} + j\omega \left(\frac{L_0 + L_\infty (f / f_m)^{Nb}}{1 + (f / f_m)^{Nb}} \right)$$

$$\gamma = g_0 f^{Nge} + j\omega (C_\infty + C_0 / f^{Nce})$$

Unless the exact parameters used in Appendix A can be established we suggest using the parameters given in [2]:

Table 1. BTm parameter set

	Roc	Linf	Fr	LoLinf	Fm	Nb	Cinf
ADSL_PE032	409	500.00µH	270.59kHz	107.64µH	608.77kHz	5.2464	40.000nF
ADSL_PE04	280	427.12µH	251.91kHz	160.01µH	739.05kHz	1.3952	50.000nF
ADSL_PE05	179	544.25µH	135.30kHz	129.32µH	580.92kHz	1.3013	50.000nF
ADSL_PE063	113	477.42µH	79.733kHz	221.84µH	265.70kHz	1.0978	45.000nF
ADSL_PE09	55	520.45µH	31.207kHz	230.34µH	124.04kHz	0.9605	40.000nF

```
Comment:
Ros = 0; as  = 0; C0  = 0; Nce  = 0; g0  = 0;
ac  = (Ro^2/Fr)^2;
L0  = LoLinf + Linf;
```

The MAR model

The MAR model was introduced by Mossun in [3] and was further analyzed in [4]. Being the only model that by design adheres to the Hilbert relation between real and imaginary parts of the parameters it is the only model that is guaranteed to give a reasonable time-domain behavior.

The MAR1 model is given by:

$$Z_0 = j\omega L_\infty + R_0 \left(0.25 + 0.75\sqrt{1 + as(s+b)/(s+c)}\right),$$

$$\gamma = \omega C_f (j + \tan\partial) = jwC_{1MHz} \times (jf_{1MHz})^{-2\partial/\pi},$$

where

$$s = \frac{\mu_0 jf}{0.75^2 R_0} = \frac{jf}{447.6 R_0},$$

and using the relation $\mu_0 = 4\pi 10^{-4}$ [H/km] and $C_f = \frac{C_{1MHz}}{f_{MHz}^{2\partial/\pi}}$

The basic MAR model (MAR1) parameters are then

L_∞ is the high frequency inductance per km,

R_0 is the DC resistance per km,

a is a Proximity factor (by which effective skin effect frequency is increased),

b and *c* are skin effect shape coefficients,

∂ shunt capacity loss angle (constant)

C_{1MHz} is the capacitance per km at 1 MHz.

The simplified MAR model (MAR2) uses b=2 and c=2.765 fixed.

We have tried to fit a MAR2 model to the current tabulated data as well as to the corresponding BT model. The resulting optimal parameters are:

Table 2. MAR2opt parameter set

	Ro	Linf	a	C1M	delta
ETSI-ADSL-PE032mar2	400.666842	411.961536	2.156655	39.639546	0.002840
ETSI-ADSL-PE04mar2	277.623806	421.576013	1.470148	49.792437	0.001123
ETSI-ADSL-PE05mar2	179.460137	516.017173	1.705113	49.840489	0.002647
ETSI-ADSL-PE063mar2	111.100648	471.310664	1.948990	44.685737	0.003210
ETSI-ADSL-PE09mar2	54.753441	502.965928	2.446506	39.855129	0.002673

We also have designed, by hand, a parameter set that fits the original data well and tries to match the RLCG values better than the directly optimized version.

Table 3. MAR2hand parameter set

	Ro	Linf	a	C1M	delta
ADSL_PE032	409	0.00040	2.05	4e-08	0
ADSL_PE04	280	0.0004	1.44	5e-08	0
ADSL_PE05	179	0.0005	1.79	5e-08	0
ADSL_PE063	113	0.00045	2.01	4.5e-08	0
ADSL_PE09	55	0.0005	2.56	4e-08	0

The most important parameter for our simulations is the transfer function (s21). Thus we want to compare our parametric models towards the tabulated data. In Figures 1 below we show the resulting attenuation curve for the four cases on different cables. In table 4 we also give the numbers for max and mean error. It is clear that the MAR models can not exactly match the characteristics of the tables (and should not!), but they seem to be so close that no major change in e.g. performance number are to be expected.

In Appendix A we have tabulated the corresponding RLCG values (and attenuation) for the three parametric models.

Table 4. Comparing max error and mean error for the three models

```
ETSI-ADSL-PE032 max  dev: BTm = 0.000136, MAR2opt = 0.382942, MAR2hand = 0.512446
ETSI-ADSL-PE04  max  dev: BTm = 0.000055, MAR2opt = 0.180922, MAR2hand = 0.446823
ETSI-ADSL-PE05  max  dev: BTm = 0.000380, MAR2opt = 0.090917, MAR2hand = 0.295414
ETSI-ADSL-PE063 max  dev: BTm = 0.000146, MAR2opt = 0.141784, MAR2hand = 0.383427
ETSI-ADSL-PE09  max  dev: BTm = 0.000051, MAR2opt = 0.060151, MAR2hand = 0.098394

ETSI-ADSL-PE032 mean dev: BTm = 0.000055, MAR2opt = 0.161507, MAR2hand = 0.206807
ETSI-ADSL-PE04  mean dev: BTm = 0.000020, MAR2opt = 0.056608, MAR2hand = 0.273405
ETSI-ADSL-PE05  mean dev: BTm = 0.000181, MAR2opt = 0.036800, MAR2hand = 0.156808
ETSI-ADSL-PE063 mean dev: BTm = 0.000066, MAR2opt = 0.069994, MAR2hand = 0.235836
ETSI-ADSL-PE09  mean dev: BTm = 0.000022, MAR2opt = 0.024369, MAR2hand = 0.044822
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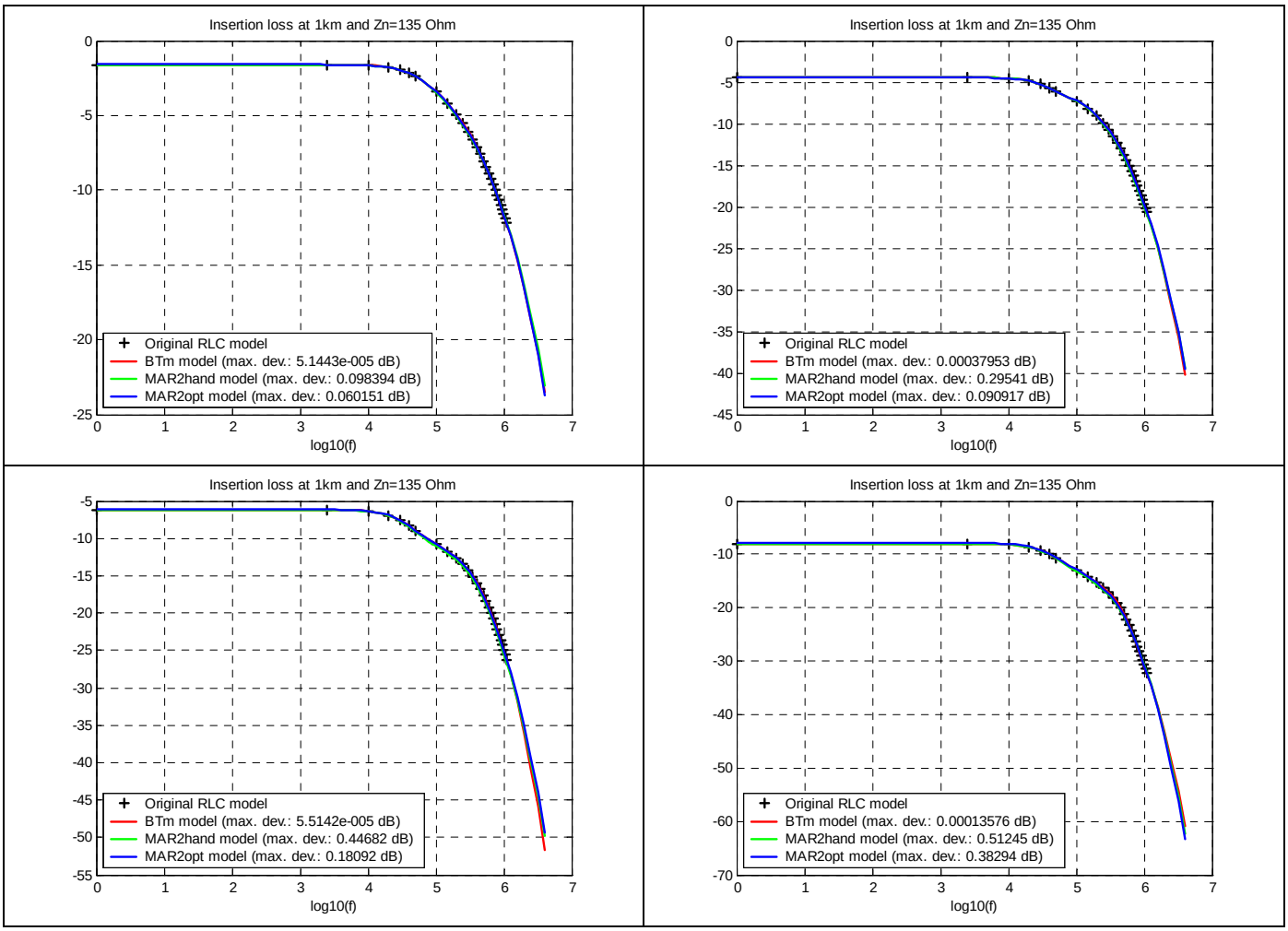

Figure 1. Showing the insertion loss curves for the original tables as well as the three considered parametric models.

3. Conclusion

For the revision of TS 101 388 we propose the use of MAR2 parametric models for specifying the cable characteristics as defined in Table 2

If this is not acceptable we then propose as a compromise the use of BT parametric models as specified in Table 1

4. References

[1] ETSI RTS/TM-06025 (Draft), ADSL – European specific requirements, ETSI (m01p07a2), Version 1a, September 2001.

[2] ITU-T Recommendation G.996.1 “Transmission Systems and Media – Test Procedures for Digital Subscriber Line (DSL) Transceivers”, 1999.

[3] Musson, J., “Maximum likelihood parameters of pair cables, ETSI TM6 TD08 Madrid, Spain, (981t08a1), Jan. 1998.

[4] Heylen, L., J. Musson, “Cable models predict phyically impossible behaviour in time domain”, ETSI TM6 TD53 Amsterdam, Netherlands, (994t53a0), Nov. 1999.

[5] Jacobsson, K. “Proposal to increase frequency range of primary parameter tables”, ETSI TM6 TD27 Torino, Italy, (021t27a0), 2002.

[6] ETSI TM6 Permanent Document TM6(97)02, “Cable reference models for simulating metallic access networks”, 970p02r3, Revision 3, Aug. 1998.

[7] J.W. Cook: ' Parametric modelling of twisted pair cables for VDSL ', ETSI contribution TD22, Vienna, Austria, march 1996.

[8] Nordström T., D. Bengtsson, *FTW xDSL simulation tool*, Version 2.3beta3, 2001. Version 2.2 is available at <http://www.xdsl.ftw.at/xdslsimu/ >.

Appendix A

BTm model

RLCG values for ETSI-ADSL-PE032m

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	409.000	607.640	40.000	0.000	9.036
2.50	409.009	607.640	40.000	0.000	9.042
10.00	409.140	607.640	40.000	0.000	9.129
20.00	409.557	607.640	40.000	0.000	9.370
30.00	410.251	607.640	40.000	0.000	9.681
40.00	411.216	607.640	40.000	0.000	9.996
50.00	412.447	607.640	40.000	0.000	10.281
100.00	422.302	607.632	40.000	0.000	11.138
150.00	437.338	607.571	40.000	0.000	11.542
200.00	456.086	607.328	40.000	0.000	11.846
250.00	477.230	606.640	40.000	0.000	12.105
300.00	499.758	605.075	40.000	0.000	12.348
350.00	522.969	602.047	40.000	0.000	12.578
400.00	546.397	596.935	40.000	0.000	12.802
450.00	569.750	589.338	40.000	0.000	13.022
500.00	592.846	579.377	40.000	0.000	13.240
550.00	615.578	567.823	40.000	0.000	13.453
600.00	637.888	555.868	40.000	0.000	13.659
650.00	659.745	544.658	40.000	0.000	13.853
700.00	681.141	534.942	40.000	0.000	14.034
750.00	702.075	526.992	40.000	0.000	14.201
800.00	722.559	520.732	40.000	0.000	14.355
850.00	742.604	515.919	40.000	0.000	14.497
900.00	762.227	512.265	40.000	0.000	14.628
950.00	781.445	509.503	40.000	0.000	14.750
1000.00	800.275	507.415	40.000	0.000	14.864
1050.00	818.735	505.831	40.000	0.000	14.972
1100.00	836.840	504.623	40.000	0.000	15.074
1150.00	854.608	503.694	40.000	0.000	15.170
1200.00	872.053	502.975	40.000	0.000	15.262
1500.00	970.711	500.941	40.000	0.000	15.743
2000.00	1116.997	500.209	40.000	0.000	16.361
3000.00	1364.608	500.025	40.000	0.000	17.237
4000.00	1574.321	500.006	40.000	0.000	17.860
5000.00	1759.422	500.002	40.000	0.000	18.345

RLCG values for ETSI-ADSL-PE04m

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	280.000	587.130	50.000	0.000	7.910
2.50	280.007	587.073	50.000	0.000	7.919
10.00	280.110	586.736	50.000	0.000	8.051
20.00	280.440	586.097	50.000	0.000	8.399
30.00	280.988	585.320	50.000	0.000	8.815
40.00	281.748	584.441	50.000	0.000	9.202
50.00	282.718	583.481	50.000	0.000	9.522
100.00	290.433	577.877	50.000	0.000	10.320
150.00	302.070	571.524	50.000	0.000	10.708
200.00	316.393	564.888	50.000	0.000	11.007
250.00	332.347	558.232	50.000	0.000	11.291
300.00	349.167	551.714	50.000	0.000	11.550
350.00	366.344	545.430	50.000	0.000	11.801
400.00	383.561	539.436	50.000	0.000	12.032
450.00	400.626	533.759	50.000	0.000	12.253
500.00	417.427	528.409	50.000	0.000	12.457
550.00	433.904	523.385	50.000	0.000	12.651
600.00	450.026	518.677	50.000	0.000	12.831
650.00	465.785	514.272	50.000	0.000	13.003
700.00	481.179	510.153	50.000	0.000	13.163
750.00	496.217	506.304	50.000	0.000	13.315
800.00	510.911	502.707	50.000	0.000	13.458
850.00	525.273	499.343	50.000	0.000	13.595
900.00	539.319	496.197	50.000	0.000	13.724
950.00	553.063	493.253	50.000	0.000	13.848
1000.00	566.520	490.494	50.000	0.000	13.965
1050.00	579.704	487.908	50.000	0.000	14.077
1100.00	592.627	485.481	50.000	0.000	14.184
1150.00	605.303	483.202	50.000	0.000	14.287
1200.00	617.744	481.058	50.000	0.000	14.385
1500.00	688.020	470.545	50.000	0.000	14.903
2000.00	792.062	459.053	50.000	0.000	15.569
3000.00	967.963	446.968	50.000	0.000	16.498
4000.00	1116.851	440.975	50.000	0.000	17.148
5000.00	1248.233	437.509	50.000	0.000	17.647

RLCG values for ETSI-ADSL-PE05m

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	179.000	673.570	50.000	0.000	6.452
2.50	179.015	673.462	50.000	0.000	6.459
10.00	179.244	672.919	50.000	0.000	6.564
20.00	179.970	671.976	50.000	0.000	6.851
30.00	181.161	670.892	50.000	0.000	7.211
40.00	182.789	669.712	50.000	0.000	7.560
50.00	184.821	668.464	50.000	0.000	7.854
100.00	199.606	661.674	50.000	0.000	8.599
150.00	218.718	654.618	50.000	0.000	9.122
200.00	239.129	647.732	50.000	0.000	9.554
250.00	259.457	641.206	50.000	0.000	9.955
300.00	279.169	635.116	50.000	0.000	10.301
350.00	298.098	629.486	50.000	0.000	10.612
400.00	316.225	624.307	50.000	0.000	10.892
450.00	333.585	619.556	50.000	0.000	11.142
500.00	350.237	615.201	50.000	0.000	11.374
550.00	366.239	611.210	50.000	0.000	11.582
600.00	381.650	607.551	50.000	0.000	11.777
650.00	396.521	604.191	50.000	0.000	11.955
700.00	410.899	601.103	50.000	0.000	12.123
750.00	424.827	598.260	50.000	0.000	12.278
800.00	438.340	595.639	50.000	0.000	12.425
850.00	451.471	593.216	50.000	0.000	12.562
900.00	464.250	590.975	50.000	0.000	12.692
950.00	476.701	588.896	50.000	0.000	12.815
1000.00	488.848	586.965	50.000	0.000	12.932
1050.00	500.711	585.169	50.000	0.000	13.043
1100.00	512.308	583.495	50.000	0.000	13.149
1150.00	523.655	581.932	50.000	0.000	13.250
1200.00	534.769	580.470	50.000	0.000	13.347
1500.00	597.213	573.400	50.000	0.000	13.854
2000.00	688.993	565.815	50.000	0.000	14.504
3000.00	843.306	557.907	50.000	0.000	15.412
4000.00	973.550	553.963	50.000	0.000	16.050
5000.00	1088.350	551.655	50.000	0.000	16.543

RLCG values for ETSI-ADSL-PE063m

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	113.000	699.260	45.000	0.000	4.824
2.50	113.028	697.945	45.000	0.000	4.829
10.00	113.442	693.363	45.000	0.000	4.898
20.00	114.737	687.010	45.000	0.000	5.105
30.00	116.803	680.716	45.000	0.000	5.399
40.00	119.523	674.594	45.000	0.000	5.723
50.00	122.768	668.691	45.000	0.000	6.035
100.00	143.116	642.718	45.000	0.000	7.058
150.00	164.939	622.050	45.000	0.000	7.805
200.00	185.690	605.495	45.000	0.000	8.389
250.00	204.997	592.047	45.000	0.000	8.893
300.00	222.962	580.959	45.000	0.000	9.297
350.00	239.765	571.689	45.000	0.000	9.661
400.00	255.576	563.843	45.000	0.000	9.966
450.00	270.534	557.127	45.000	0.000	10.248
500.00	284.755	551.321	45.000	0.000	10.491
550.00	298.331	546.258	45.000	0.000	10.718
600.00	311.341	541.807	45.000	0.000	10.920
650.00	323.845	537.866	45.000	0.000	11.110
700.00	335.898	534.355	45.000	0.000	11.283
750.00	347.544	531.209	45.000	0.000	11.445
800.00	358.821	528.375	45.000	0.000	11.596
850.00	369.760	525.810	45.000	0.000	11.737
900.00	380.390	523.478	45.000	0.000	11.871
950.00	390.736	521.349	45.000	0.000	11.995
1000.00	400.818	519.399	45.000	0.000	12.115
1050.00	410.656	517.606	45.000	0.000	12.227
1100.00	420.266	515.953	45.000	0.000	12.336
1150.00	429.664	514.424	45.000	0.000	12.438
1200.00	438.862	513.006	45.000	0.000	12.537
1500.00	490.469	506.280	45.000	0.000	13.048
2000.00	566.170	499.233	45.000	0.000	13.701
3000.00	693.261	491.908	45.000	0.000	14.611
4000.00	800.447	488.175	45.000	0.000	15.251
5000.00	894.895	485.928	45.000	0.000	15.744

RLCG values for ETSI-ADSL-PE09m

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	55.000	750.787	40.000	0.000	2.069
2.50	55.088	745.498	40.000	0.000	2.076
10.00	56.361	731.955	40.000	0.000	2.181
20.00	59.941	716.770	40.000	0.000	2.478
30.00	64.777	703.870	40.000	0.000	2.883
40.00	70.127	692.703	40.000	0.000	3.326
50.00	75.586	682.910	40.000	0.000	3.763
100.00	100.769	647.493	40.000	0.000	5.311
150.00	121.866	625.138	40.000	0.000	6.226
200.00	140.076	609.652	40.000	0.000	6.907
250.00	156.274	598.256	40.000	0.000	7.429
300.00	170.988	589.504	40.000	0.000	7.860
350.00	184.557	582.563	40.000	0.000	8.219
400.00	197.208	576.919	40.000	0.000	8.534
450.00	209.105	572.237	40.000	0.000	8.805
500.00	220.366	568.288	40.000	0.000	9.054
550.00	231.082	564.911	40.000	0.000	9.269
600.00	241.327	561.989	40.000	0.000	9.475
650.00	251.156	559.435	40.000	0.000	9.654
700.00	260.616	557.184	40.000	0.000	9.828
750.00	269.746	555.184	40.000	0.000	9.982
800.00	278.578	553.395	40.000	0.000	10.133
850.00	287.139	551.785	40.000	0.000	10.268
900.00	295.453	550.328	40.000	0.000	10.400
950.00	303.540	549.003	40.000	0.000	10.522
1000.00	311.417	547.794	40.000	0.000	10.639
1050.00	319.100	546.684	40.000	0.000	10.749
1100.00	326.603	545.663	40.000	0.000	10.854
1150.00	333.938	544.721	40.000	0.000	10.955
1200.00	341.115	543.847	40.000	0.000	11.050
1500.00	381.355	539.711	40.000	0.000	11.551
2000.00	440.330	535.362	40.000	0.000	12.193
3000.00	539.273	530.767	40.000	0.000	13.091
4000.00	622.692	528.362	40.000	0.000	13.725
5000.00	696.187	526.878	40.000	0.000	14.215

MAR2hand model

RLCG values for ETSI-ADSL-PE032_MAR2hand

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	409.000	597.709	40.000	0.000	9.036
2.50	409.010	597.705	40.000	0.000	9.042
10.00	409.157	597.637	40.000	0.000	9.130
20.00	409.628	597.423	40.000	0.000	9.374
30.00	410.404	597.072	40.000	0.000	9.689
40.00	411.477	596.591	40.000	0.000	10.008
50.00	412.832	595.992	40.000	0.000	10.298
100.00	423.266	591.637	40.000	0.000	11.181
150.00	438.299	586.044	40.000	0.000	11.610
200.00	456.365	580.110	40.000	0.000	11.931
250.00	476.480	574.214	40.000	0.000	12.203
300.00	497.985	568.489	40.000	0.000	12.456
350.00	520.385	562.986	40.000	0.000	12.692
400.00	543.290	557.728	40.000	0.000	12.918
450.00	566.394	552.727	40.000	0.000	13.130
500.00	589.465	547.990	40.000	0.000	13.332
550.00	612.334	543.518	40.000	0.000	13.522
600.00	634.882	539.306	40.000	0.000	13.702
650.00	657.033	535.345	40.000	0.000	13.872
700.00	678.738	531.623	40.000	0.000	14.032
750.00	699.973	528.127	40.000	0.000	14.184
800.00	720.727	524.843	40.000	0.000	14.328
850.00	741.002	521.756	40.000	0.000	14.464
900.00	760.805	518.851	40.000	0.000	14.593
950.00	780.150	516.116	40.000	0.000	14.715
1000.00	799.054	513.537	40.000	0.000	14.832
1050.00	817.532	511.103	40.000	0.000	14.943
1100.00	835.604	508.803	40.000	0.000	15.050
1150.00	853.288	506.625	40.000	0.000	15.151
1200.00	870.602	504.562	40.000	0.000	15.249
1500.00	967.649	494.145	40.000	0.000	15.759
2000.00	1109.238	481.876	40.000	0.000	16.412
3000.00	1344.763	466.963	40.000	0.000	17.323
4000.00	1541.920	457.985	40.000	0.000	17.962
5000.00	1714.955	451.844	40.000	0.000	18.455

RLCG values for ETSI-ADSL-PE04_MAR2hand

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	280.000	538.879	50.000	0.000	7.910
2.50	280.005	538.878	50.000	0.000	7.920
10.00	280.085	538.867	50.000	0.000	8.058
20.00	280.340	538.830	50.000	0.000	8.424
30.00	280.767	538.767	50.000	0.000	8.857
40.00	281.367	538.675	50.000	0.000	9.259
50.00	282.141	538.549	50.000	0.000	9.592
100.00	288.652	537.305	50.000	0.000	10.416
150.00	299.321	534.854	50.000	0.000	10.797
200.00	313.303	531.325	50.000	0.000	11.093
250.00	329.490	527.107	50.000	0.000	11.377
300.00	346.907	522.580	50.000	0.000	11.640
350.00	364.841	518.021	50.000	0.000	11.896
400.00	382.829	513.598	50.000	0.000	12.131
450.00	400.588	509.402	50.000	0.000	12.355
500.00	417.960	505.472	50.000	0.000	12.560
550.00	434.867	501.817	50.000	0.000	12.753
600.00	451.275	498.431	50.000	0.000	12.931
650.00	467.182	495.299	50.000	0.000	13.099
700.00	482.600	492.400	50.000	0.000	13.254
750.00	497.550	489.714	50.000	0.000	13.401
800.00	512.058	487.223	50.000	0.000	13.538
850.00	526.148	484.907	50.000	0.000	13.667
900.00	539.848	482.749	50.000	0.000	13.790
950.00	553.181	480.735	50.000	0.000	13.906
1000.00	566.173	478.851	50.000	0.000	14.016
1050.00	578.843	477.085	50.000	0.000	14.120
1100.00	591.213	475.425	50.000	0.000	14.221
1150.00	603.301	473.863	50.000	0.000	14.316
1200.00	615.124	472.389	50.000	0.000	14.408
1500.00	681.287	465.035	50.000	0.000	14.887
2000.00	777.856	456.501	50.000	0.000	15.504
3000.00	939.096	446.224	50.000	0.000	16.372
4000.00	1074.593	440.053	50.000	0.000	16.987
5000.00	1193.785	435.831	50.000	0.000	17.464

RLCG values for ETSI-ADSL-PE05_MAR2hand

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	179.000	672.634	50.000	0.000	6.452
2.50	179.016	672.622	50.000	0.000	6.459
10.00	179.250	672.447	50.000	0.000	6.564
20.00	179.991	671.899	50.000	0.000	6.851
30.00	181.197	671.024	50.000	0.000	7.212
40.00	182.832	669.870	50.000	0.000	7.560
50.00	184.853	668.489	50.000	0.000	7.855
100.00	199.356	659.609	50.000	0.000	8.600
150.00	218.343	649.560	50.000	0.000	9.132
200.00	239.102	639.729	50.000	0.000	9.580
250.00	260.050	630.709	50.000	0.000	10.002
300.00	280.409	622.688	50.000	0.000	10.363
350.00	299.872	615.651	50.000	0.000	10.687
400.00	318.369	609.495	50.000	0.000	10.974
450.00	335.933	604.098	50.000	0.000	11.229
500.00	352.638	599.342	50.000	0.000	11.461
550.00	368.564	595.127	50.000	0.000	11.669
600.00	383.791	591.368	50.000	0.000	11.862
650.00	398.391	587.994	50.000	0.000	12.036
700.00	412.427	584.949	50.000	0.000	12.200
750.00	425.955	582.186	50.000	0.000	12.350
800.00	439.023	579.665	50.000	0.000	12.493
850.00	451.672	577.354	50.000	0.000	12.625
900.00	463.939	575.227	50.000	0.000	12.750
950.00	475.855	573.262	50.000	0.000	12.868
1000.00	487.448	571.440	50.000	0.000	12.980
1050.00	498.742	569.744	50.000	0.000	13.086
1100.00	509.760	568.161	50.000	0.000	13.188
1150.00	520.520	566.679	50.000	0.000	13.284
1200.00	531.038	565.288	50.000	0.000	13.377
1500.00	589.861	558.432	50.000	0.000	13.860
2000.00	675.719	550.610	50.000	0.000	14.481
3000.00	819.217	541.310	50.000	0.000	15.354
4000.00	939.911	535.763	50.000	0.000	15.972
5000.00	1046.126	531.980	50.000	0.000	16.452

RLCG values for ETSI-ADSL-PE063_MAR2hand

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	113.000	643.852	45.000	0.000	4.824
2.50	113.034	643.798	45.000	0.000	4.830
10.00	113.535	643.011	45.000	0.000	4.913
20.00	115.058	640.708	45.000	0.000	5.153
30.00	117.384	637.419	45.000	0.000	5.482
40.00	120.319	633.602	45.000	0.000	5.835
50.00	123.712	629.559	45.000	0.000	6.167
100.00	144.475	609.646	45.000	0.000	7.209
150.00	167.175	592.455	45.000	0.000	7.969
200.00	188.972	578.478	45.000	0.000	8.567
250.00	209.125	567.292	45.000	0.000	9.073
300.00	227.660	558.275	45.000	0.000	9.477
350.00	244.790	550.895	45.000	0.000	9.833
400.00	260.737	544.751	45.000	0.000	10.130
450.00	275.690	539.555	45.000	0.000	10.400
500.00	289.801	535.096	45.000	0.000	10.635
550.00	303.191	531.222	45.000	0.000	10.850
600.00	315.956	527.819	45.000	0.000	11.044
650.00	328.175	524.802	45.000	0.000	11.222
700.00	339.910	522.103	45.000	0.000	11.387
750.00	351.215	519.673	45.000	0.000	11.539
800.00	362.133	517.469	45.000	0.000	11.683
850.00	372.701	515.459	45.000	0.000	11.815
900.00	382.952	513.616	45.000	0.000	11.943
950.00	392.910	511.920	45.000	0.000	12.060
1000.00	402.602	510.351	45.000	0.000	12.174
1050.00	412.046	508.894	45.000	0.000	12.280
1100.00	421.261	507.538	45.000	0.000	12.383
1150.00	430.263	506.270	45.000	0.000	12.480
1200.00	439.067	505.082	45.000	0.000	12.574
1500.00	488.337	499.249	45.000	0.000	13.060
2000.00	560.357	492.628	45.000	0.000	13.686
3000.00	680.905	484.780	45.000	0.000	14.566
4000.00	782.389	480.108	45.000	0.000	15.189
5000.00	871.738	476.922	45.000	0.000	15.672

RLCG values for ETSI-ADSL-PE09_MAR2hand

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	55.000	746.896	40.000	0.000	2.069
2.50	55.127	746.266	40.000	0.000	2.079
10.00	56.825	738.347	40.000	0.000	2.212
20.00	60.868	722.719	40.000	0.000	2.535
30.00	65.709	708.201	40.000	0.000	2.934
40.00	70.897	695.713	40.000	0.000	3.364
50.00	76.241	684.821	40.000	0.000	3.793
100.00	102.005	645.560	40.000	0.000	5.369
150.00	123.856	621.834	40.000	0.000	6.307
200.00	142.416	606.288	40.000	0.000	6.991
250.00	158.682	595.294	40.000	0.000	7.506
300.00	173.303	587.051	40.000	0.000	7.928
350.00	186.683	580.598	40.000	0.000	8.276
400.00	199.091	575.377	40.000	0.000	8.581
450.00	210.710	571.044	40.000	0.000	8.842
500.00	221.675	567.376	40.000	0.000	9.083
550.00	232.085	564.219	40.000	0.000	9.291
600.00	242.016	561.465	40.000	0.000	9.489
650.00	251.530	559.037	40.000	0.000	9.662
700.00	260.675	556.874	40.000	0.000	9.831
750.00	269.491	554.931	40.000	0.000	9.979
800.00	278.012	553.175	40.000	0.000	10.125
850.00	286.264	551.576	40.000	0.000	10.256
900.00	294.273	550.113	40.000	0.000	10.384
950.00	302.059	548.767	40.000	0.000	10.502
1000.00	309.639	547.525	40.000	0.000	10.615
1050.00	317.029	546.372	40.000	0.000	10.722
1100.00	324.242	545.299	40.000	0.000	10.824
1150.00	331.292	544.298	40.000	0.000	10.922
1200.00	338.187	543.360	40.000	0.000	11.014
1500.00	376.815	538.759	40.000	0.000	11.503
2000.00	433.353	533.545	40.000	0.000	12.132
3000.00	528.095	527.371	40.000	0.000	13.015
4000.00	607.910	523.695	40.000	0.000	13.641
5000.00	678.204	521.189	40.000	0.000	14.126

MAR2opt model

RLCG values for ETSI-ADSL-PE032_MAR2opt

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	400.667	619.957	40.642	0.000	8.978
2.50	400.678	619.951	40.071	0.002	8.985
10.00	400.850	619.863	39.971	0.007	9.073
20.00	401.396	619.583	39.921	0.014	9.311
30.00	402.296	619.124	39.891	0.021	9.618
40.00	403.534	618.501	39.871	0.028	9.930
50.00	405.093	617.727	39.855	0.036	10.214
100.00	416.893	612.251	39.805	0.071	11.087
150.00	433.461	605.504	39.776	0.106	11.521
200.00	452.966	598.604	39.755	0.142	11.854
250.00	474.373	591.936	39.739	0.177	12.139
300.00	497.031	585.593	39.726	0.213	12.404
350.00	520.463	579.586	39.715	0.248	12.650
400.00	544.291	573.912	39.705	0.283	12.884
450.00	568.225	568.564	39.697	0.319	13.104
500.00	592.043	563.534	39.689	0.354	13.313
550.00	615.587	558.812	39.682	0.389	13.508
600.00	638.750	554.385	39.676	0.425	13.693
650.00	661.463	550.239	39.670	0.460	13.867
700.00	683.686	546.355	39.665	0.495	14.031
750.00	705.399	542.717	39.660	0.531	14.185
800.00	726.599	539.308	39.655	0.566	14.332
850.00	747.291	536.109	39.651	0.601	14.470
900.00	767.487	533.106	39.647	0.637	14.601
950.00	787.205	530.282	39.643	0.672	14.726
1000.00	806.462	527.623	39.639	0.707	14.844
1050.00	825.278	525.117	39.636	0.743	14.957
1100.00	843.673	522.750	39.633	0.778	15.065
1150.00	861.668	520.512	39.629	0.813	15.168
1200.00	879.282	518.393	39.626	0.849	15.267
1500.00	977.948	507.719	39.610	1.060	15.785
2000.00	1121.796	495.187	39.590	1.413	16.447
3000.00	1360.991	479.992	39.561	2.118	17.372
4000.00	1561.193	470.857	39.540	2.822	18.023
5000.00	1736.892	464.614	39.524	3.526	18.525

RLCG values for ETSI-ADSL-PE04_MAR2opt

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	277.624	563.362	50.287	0.000	7.883
2.50	277.630	563.361	50.006	0.001	7.894
10.00	277.715	563.346	49.957	0.004	8.030
20.00	277.990	563.297	49.932	0.007	8.386
30.00	278.448	563.212	49.917	0.011	8.808
40.00	279.091	563.091	49.907	0.014	9.200
50.00	279.919	562.929	49.899	0.018	9.524
100.00	286.818	561.422	49.874	0.035	10.322
150.00	297.967	558.651	49.860	0.053	10.700
200.00	312.414	554.823	49.850	0.070	10.997
250.00	329.012	550.352	49.842	0.088	11.286
300.00	346.779	545.622	49.835	0.106	11.552
350.00	365.012	540.899	49.830	0.123	11.812
400.00	383.253	536.345	49.825	0.141	12.050
450.00	401.232	532.043	49.821	0.158	12.277
500.00	418.797	528.026	49.817	0.176	12.483
550.00	435.873	524.299	49.814	0.193	12.678
600.00	452.435	520.853	49.811	0.211	12.857
650.00	468.482	517.669	49.808	0.228	13.026
700.00	484.030	514.726	49.805	0.246	13.182
750.00	499.100	512.003	49.803	0.264	13.330
800.00	513.720	509.478	49.800	0.281	13.467
850.00	527.917	507.133	49.798	0.299	13.598
900.00	541.717	504.949	49.796	0.316	13.721
950.00	555.148	502.912	49.794	0.334	13.838
1000.00	568.231	501.007	49.792	0.351	13.948
1050.00	580.991	499.222	49.791	0.369	14.054
1100.00	593.447	497.545	49.789	0.387	14.154
1150.00	605.618	495.967	49.787	0.404	14.250
1200.00	617.522	494.479	49.786	0.422	14.342
1500.00	684.126	487.056	49.778	0.527	14.825
2000.00	781.323	478.452	49.768	0.702	15.446
3000.00	943.592	468.098	49.753	1.053	16.320
4000.00	1079.945	461.883	49.743	1.404	16.941
5000.00	1199.885	457.633	49.735	1.755	17.424

RLCG values for ETSI-ADSL-PE05_MAR2opt

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	179.460	680.465	51.014	0.000	6.461
2.50	179.474	680.456	50.346	0.002	6.470
10.00	179.678	680.325	50.229	0.008	6.579
20.00	180.327	679.915	50.170	0.017	6.868
30.00	181.390	679.250	50.136	0.025	7.226
40.00	182.844	678.359	50.111	0.033	7.568
50.00	184.659	677.269	50.093	0.042	7.855
100.00	198.066	669.807	50.034	0.083	8.572
150.00	216.106	660.758	50.000	0.125	9.087
200.00	236.078	651.597	49.976	0.166	9.527
250.00	256.350	643.048	49.957	0.208	9.942
300.00	276.111	635.381	49.942	0.249	10.301
350.00	295.036	628.617	49.929	0.291	10.622
400.00	313.042	622.681	49.917	0.332	10.908
450.00	330.152	617.464	49.907	0.374	11.162
500.00	346.432	612.860	49.899	0.415	11.395
550.00	361.959	608.775	49.891	0.456	11.602
600.00	376.810	605.127	49.883	0.498	11.795
650.00	391.051	601.852	49.877	0.539	11.970
700.00	404.745	598.894	49.870	0.581	12.135
750.00	417.945	596.207	49.864	0.622	12.286
800.00	430.698	593.756	49.859	0.663	12.429
850.00	443.043	591.508	49.854	0.705	12.562
900.00	455.016	589.439	49.849	0.746	12.689
950.00	466.648	587.526	49.845	0.788	12.807
1000.00	477.965	585.752	49.840	0.829	12.920
1050.00	488.991	584.100	49.836	0.870	13.028
1100.00	499.747	582.558	49.832	0.912	13.130
1150.00	510.252	581.115	49.829	0.953	13.228
1200.00	520.523	579.760	49.825	0.994	13.321
1500.00	577.963	573.077	49.806	1.243	13.812
2000.00	661.817	565.449	49.782	1.656	14.444
3000.00	801.991	556.372	49.748	2.482	15.337
4000.00	919.903	550.957	49.724	3.308	15.974
5000.00	1023.677	547.263	49.705	4.133	16.471

RLCG values for ETSI-ADSL-PE063_MAR2opt

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	111.101	659.278	45.965	0.000	4.762
2.50	111.132	659.231	45.236	0.002	4.770
10.00	111.603	658.529	45.108	0.009	4.857
20.00	113.040	656.460	45.044	0.018	5.093
30.00	115.250	653.474	45.007	0.027	5.413
40.00	118.061	649.964	44.980	0.036	5.754
50.00	121.332	646.199	44.960	0.045	6.075
100.00	141.575	627.154	44.896	0.091	7.101
150.00	163.793	610.394	44.859	0.136	7.861
200.00	185.100	596.723	44.833	0.181	8.458
250.00	204.775	585.785	44.812	0.226	8.965
300.00	222.859	576.974	44.796	0.271	9.368
350.00	239.566	569.768	44.781	0.316	9.727
400.00	255.118	563.771	44.769	0.361	10.024
450.00	269.701	558.700	44.758	0.406	10.296
500.00	283.462	554.350	44.749	0.451	10.531
550.00	296.521	550.571	44.740	0.496	10.749
600.00	308.971	547.252	44.732	0.541	10.943
650.00	320.889	544.309	44.725	0.586	11.125
700.00	332.337	541.677	44.718	0.631	11.290
750.00	343.365	539.306	44.712	0.676	11.446
800.00	354.016	537.156	44.706	0.721	11.590
850.00	364.327	535.196	44.700	0.766	11.726
900.00	374.327	533.399	44.695	0.811	11.854
950.00	384.044	531.744	44.690	0.856	11.974
1000.00	393.500	530.213	44.686	0.901	12.090
1050.00	402.716	528.793	44.681	0.946	12.198
1100.00	411.708	527.469	44.677	0.991	12.303
1150.00	420.493	526.233	44.673	1.036	12.401
1200.00	429.083	525.074	44.669	1.081	12.497
1500.00	477.167	519.383	44.648	1.351	12.995
2000.00	547.463	512.923	44.622	1.800	13.637
3000.00	665.137	505.264	44.585	2.698	14.546
4000.00	764.210	500.704	44.559	3.595	15.195
5000.00	851.438	497.594	44.539	4.491	15.701

RLCG values for ETSI-ADSL-PE09_MAR2opt

f [kHz]	R [Ohm]	L [uH]	C [nF]	G [mS]	Att [dB]
0.00	54.753	738.916	40.803	0.000	2.052
2.50	54.868	738.384	40.263	0.002	2.064
10.00	56.414	731.597	40.169	0.007	2.197
20.00	60.185	717.741	40.121	0.013	2.518
30.00	64.792	704.451	40.094	0.020	2.916
40.00	69.782	692.772	40.074	0.027	3.345
50.00	74.952	682.448	40.059	0.034	3.772
100.00	99.997	644.656	40.011	0.067	5.337
150.00	121.273	621.637	39.984	0.101	6.274
200.00	139.352	606.527	39.964	0.134	6.959
250.00	155.201	595.833	39.949	0.168	7.476
300.00	169.448	587.812	39.937	0.201	7.900
350.00	182.489	581.529	39.926	0.235	8.251
400.00	194.583	576.445	39.917	0.268	8.560
450.00	205.910	572.226	39.909	0.302	8.824
500.00	216.599	568.653	39.902	0.335	9.067
550.00	226.747	565.578	39.896	0.369	9.278
600.00	236.430	562.895	39.890	0.402	9.479
650.00	245.706	560.529	39.884	0.435	9.655
700.00	254.622	558.421	39.879	0.469	9.827
750.00	263.218	556.528	39.875	0.502	9.978
800.00	271.526	554.817	39.870	0.536	10.127
850.00	279.574	553.258	39.866	0.569	10.261
900.00	287.383	551.833	39.862	0.603	10.391
950.00	294.975	550.521	39.858	0.636	10.511
1000.00	302.367	549.310	39.855	0.669	10.627
1050.00	309.573	548.187	39.852	0.703	10.737
1100.00	316.607	547.141	39.849	0.736	10.841
1150.00	323.481	546.165	39.846	0.770	10.942
1200.00	330.206	545.250	39.843	0.803	11.036
1500.00	367.876	540.765	39.827	1.003	11.539
2000.00	423.014	535.681	39.808	1.337	12.188
3000.00	515.415	529.661	39.781	2.004	13.107
4000.00	593.261	526.077	39.761	2.671	13.763
5000.00	661.821	523.633	39.746	3.338	14.274