POWER HANDLING IN COMBLINE FILTERS

1. DERIVATION

For any given AC voltage condition without voltage magnification, the power capacity is related as:

$$P_{\max} = \frac{V_{\max}^2}{2Z_i}$$

Equation 1

where:

P_{max} = maximum power
V_{max} = maximum voltage
Z_i = input impedance

Equation 1 can be re-written as:

$$V_{\max} = \sqrt{2Z_i P_{\max}}$$

Equation 2

At the top of combline resonators, especially towards the centre of the filter, the voltage magnification occurs far beyond the input source voltage value. The resulting peak voltage at the top of the resonator is

$$V_{peak}(G_v) = G_v V_{\max}$$

Equation 3

where G_v is the voltage magnification factor. This factor can be obtained from a circuit simulation software. When the filter is terminated in a load that is not completely matched, there are going to be standing waves causing the voltage to rise in the line. This effect is illustrated in Figure 1 and will reduce the power-handling capability of the filter.

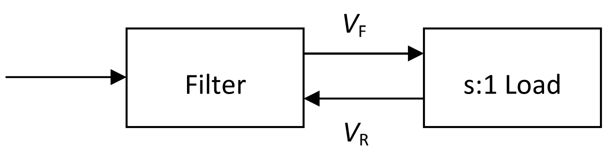

Figure 1

Voltage increase due to VSWR is:

$$V_{peak} = V_F + \Gamma \cdot V_F$$

Equation 4

where

$$\Gamma = \frac{s-1}{s+1} = \frac{V_R}{V_F}$$

Equation 5

Using Equation 4 and Equation 5, the factor by which the voltage increases can be written as

$$\frac{V_{peak}}{V_F} = 1 + \Gamma = \frac{2s}{s+1}$$

Equation 6

2. AMPLITUDE AND TEMPERATURE EFFECT

Power handling capacity decreases as the device is tested higher in altitude and in increased temperature levels. Table 1 and Table 2 list the de-rating factors for both temperature and the altitude. We define the de-rating factor for the effect of the temperature and the altitude as $A_f \cdot T_f$.

At sea level, atmospheric pressure is 760 mm Hg and the de-rating factor at room temperature is 1. At 10,000 feet and +80 °C, for example, the de-rating factor is 0.60. With the de-rating factor the cumulative voltage increase becomes

$$V_{peak} = G_v \left(\frac{2s}{s+1}\right)\left(\frac{1}{T_f A_f}\right) V_{\max}$$

Equation 7

The electric field strength can be written as

$$|E_{\max}| = \frac{V_{\max}}{g}$$

Equation 8

where g is the required gap. Substituting Equation 7 into Equation 8 we obtain

$$g = G_v \left(\frac{2s}{s+1}\right)\left(\frac{1}{T_f A_f}\right)\left(\sqrt{2 Z_i P_{\max}}\right)\left(\frac{1}{|E_{\max}|}\right)$$

Equation 9

The maximum voltage breakdown occurs at a field strength of about $2.91 \cdot 10^6$ V/m at room temperature at sea level. When we substitute this number for $|E_{max}|$ in Equation 9 and simplify, a general equation is derived for the gap as a function of VSWR, altitude, and specified peak power level to be handled as:

$$g = 3.822 \times 10^{-5} G_v \left(\frac{s}{s+1} \right) \frac{\sqrt{Z_i P_{\max}}}{T_f A_f} \text{ inches}$$

Equation 10

where:

g = Required gap

G_v = voltage magnification factor

Z_i = Input impedance (usually 50 Ω)

P_{max} = Required peak power

T_f = Temperature de-rating factor

A_f = Altitude de-rating factor

s = Load voltage standing wave ratio (VSWR)

This can be rearranged to give:

$$\frac{1}{\sqrt{P_{\max}}} = 3.822 \times 10^{-5} G_v \left(\frac{s}{s+1} \right) \frac{\sqrt{Z_i}}{g \cdot T_f A_f}$$

Equation 11

Note that Equation 10 implicitly assumes smooth surfaces. For a needlepoint situation, the break down field strength can be as little as 1 kV/mm. The breakdown at sea level at room temperature may occur around 1.2 kV/mm for needlepoint gaps. This means that from a needle point gap to a flat surface, we can increase power handling capabilities by as much as almost five times with the same gap. Additionally, high humidity can degrade power handling by as much as 20%.

Note that the following formula can be used for the de-rating factors shown in Table 1, thus making Equation 11 easier to use electronically:

$$A_f \cdot T_f (press, temp) = (-0.0000038 \cdot press - 0.0002807) \cdot temp + (0.0012940 \cdot press + 0.1018666)$$

Equation 12

where:

press = pressure in mm Hg

temp = operating temperature in °C

This formula was obtained by linear interpolation of the values given in Table 1.

Pressure	Temperature						
mm Hg	-40 °C	-20 °C	0 °C	20 °C	40 °C	60 °C	80 °C
127	0.26	0.24	0.23	0.21	0.20	0.19	0.18
254	0.47	0.44	0.42	0.39	0.37	0.34	0.32
381	0.68	0.64	0.60	0.56	0.53	0.50	0.47
508	0.87	0.82	0.77	0.72	0.68	0.64	0.60
635	1.07	0.99	0.93	0.87	0.82	0.77	0.72
762	1.25	1.17	1.10	1.03	0.97	0.91	0.85
889	1.43	1.34	1.26	1.19	1.12	1.05	0.98
1016	1.61	1.51	1.42	1.33	1.25	1.17	1.09
1143	1.79	1.68	1.58	1.49	1.40	1.31	1.22
1270	1.96	1.84	1.73	1.63	1.53	1.44	1.34
1397	2.13	2.01	1.89	1.78	1.67	1.57	1.46
1524	2.30	2.17	2.04	1.92	1.80	1.69	1.57

Table 1

Alt. ft	0	5000	10000	15000	20000	25000	30000	35000
mm Hg	760	635	508	404	338	269	218	178

Table 2

3. VERSION INFORMATION

Version 1 (12 SEP 2008): First release.

Version 2 (29 SEP 2008): Re-arranged Equation 10 to show P_{max} vs g.