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T4C baseband filter report

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The T4C baseband filter module contains 8 lowpass filters to provide the final filtering for the IF signals from the T3 IF to Baseband converter module. Since the Correlator ultimately compares all of the selected frequency bands with each other, it is critical that the power of the selected band is uniform from one T4 to the next. Refer to figure 1.

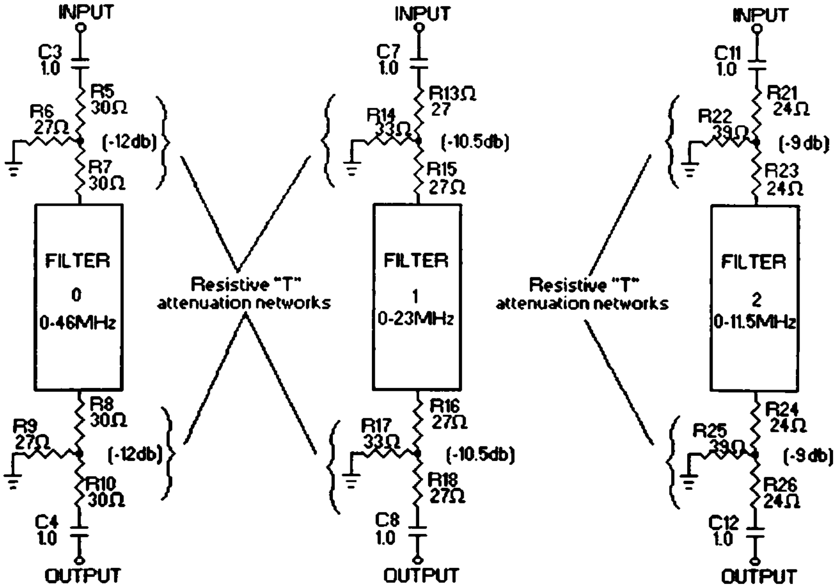


Figure 1

The 8 selectable lowpass filters within the T4 are in octave steps from 46MHz to .380MHz. Figure 1 shows a simplified schematic diagram of the first three of these lowpass filters (0,1&2). Resistive "T" attenuation networks can be seen at the input (R5,6&7 for filter '0') and output (R8,9&10 for filter '0') of each filter. These are used to ensure equal total power is present in each of the selectable frequency bands.

Lowpass filter '0' has the widest bandwidth (46MHz) and thus has the most attenuation (24dB), lowpass filter '1' has half the bandwidth (23MHz) of filter '0' and therefore half the power, so it's attenuation is 3dB less than that of filter '0'

(21dB). Lowpass filter '2' has half the bandwidth and power of filter '1' (only 11.5MHz), therefore having 3dB less attenuation than that of filter '1' and so on. Ultimately, filter '7' (the eighth filter) has 0dB of attenuation.
Ironically, it was discovered that the deterioration of these resistors had become the single most signifigant factor in overall passband flatness degradation.

In response to this discovery, it was proposed that all of the filters in each T4 should be comparatively tested and graphed for flatness.
Any filters not displaying uniform flatness (less than ± 0.1dBm from typical) were to be further scrutinized begining, of course, with the problematic attenuation network resistors.

The tests were conducted as follows:

-First, several optimally performing T4 filters were charted to create a mean response model. This model was then used as a typical reference to test other T4 filters for nonconforming responses.

-Each filter under test was injected with it's respective frequency band and at a level that was within T4 operating specifications.

-Each filter's output was then graphed on an X-Y chart recorder where each major division of the Y axis represented only 0.05dBm thus allowing results to be read with particularly high resolution.

-When the plot of a given filter's performance did not correlate with the mean reference, the problem was scrutinized to the component level, and corrected. The test on the filter was then re-initiated and the results charted on the same graph so as to be viewed before and after. See figure 2.

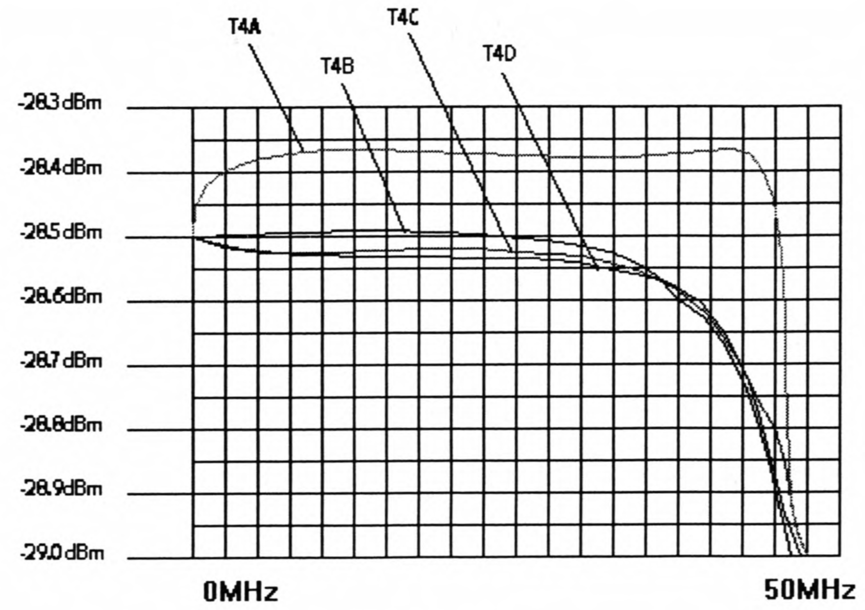


Figure 2

Figure 2 shows a comparrison plot of the 46MHz filters of 4 T4s. They are labeled A,B,C&D. In this example, it can be seen that T4 A's 46MHz filter output (represented by the uppermost trace) is much higher in power than the other 3 under test (if only by less than 0.2dBm). In this example it was found that one of the resistors (R10 in figure1) in series with the output of the filter was out of DC resistive tolerance. Instead of reading 30 ohms, it was reading 37.5 ohms. R10 was then replaced with a resistor whose reactive and DC resistive properties were measured as optimum, and the results were re-graphed on the same chart. See figure 3.

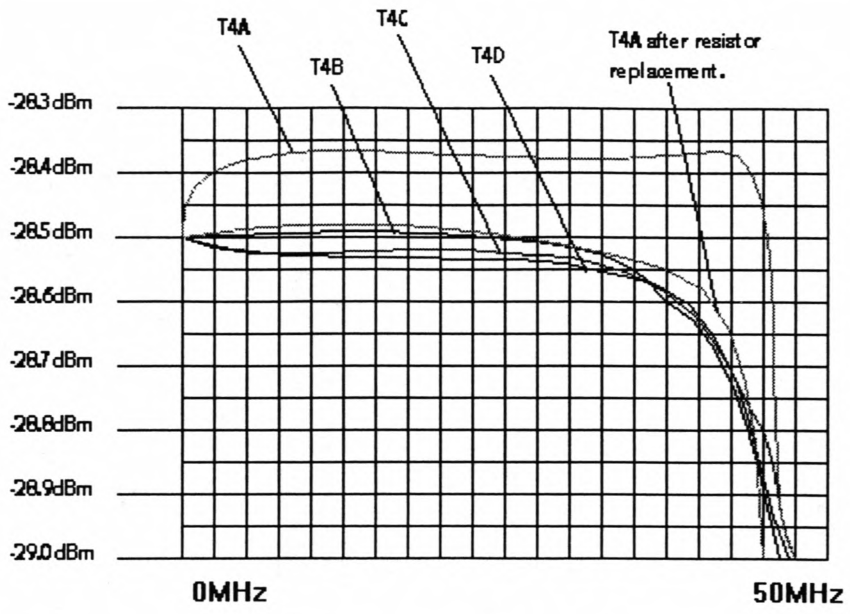


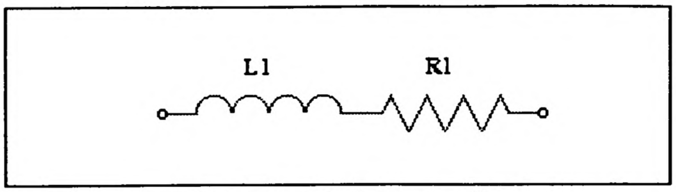
Figure 3

In figure 3 it can be seen that T4 A's *new* response is much better behaved with respect to the other modules, or the typical response.

Test results of all T4 filters showed, as predicted, that the single largest influence in the overall degredation of bandpass flatness, was indeed due to the resistive networks at the input and output of the filters.

After closer scrutinization of the offending resistors, it was discovered that while their DC resistance had changed somewhat drastically (up to 75% in many cases), their *reactive* properties were changing rather unexpectedly.

The resistors in question are all 1/4 Watt Allen Bradley part # RCR07-G-XXX-J-S (where XXX is the value of the resistor). Typically, these carbon composition resistors can be measured to have a DC resistive component, and a slight (though measurable) inductive component. This inherent inductance is due to the conductors used in the construction of the resistor. Because these components are constructed in mass, their reactive and resistive characteristics, if not identical, are at least similar. Figure 4 shows an equivelant circuit of a low value carbon composition resistors.



Resistor equivelancy circuit.

Figure 4

In figure 4, R1 represents the actual DC resistive value of the resistor. L1 represents the inherent inductance caused by the conductors used in the resistor's construction. As figure 4 illustrates, the carbon composition resistors being used are actually acting like simple circuits in themselves.

Since these resistors are not purely resistive, an HP4815A Vector Impedance Meter was used to measure the impedance and angle as a function of frequency. From these measurements, the reactance and resistance were computed. These findings were plotted on a semi-log graph. These measurements were conducted on a range of resistors of this specific type (carbon composition 1/4 Watt).

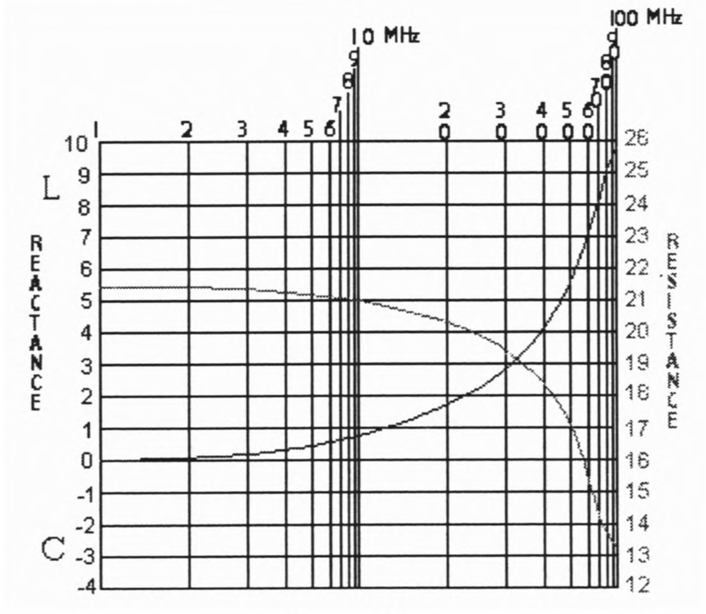


Figure 5

Figure 5 illustrates a 20 ohm 1/4 Watt carbon composition resistor's response from 1 to 100MHz. This response is typical for this type of resistor. The inductive component of the resistor (L1 in figure 4) is responsible for the inductive reactance throughout the upper end of the frequency range. Note that the only measurable reactance is inductive, and that the inductive reactance begins to steeply rise after about 10MHz. The resistive component remains relatively flat until it passes through 10MHz. As frequency increases beyond 10 MHz, the resistance begins to decrease rather steeply. The overall impedance stays about the same due to the increase in inductive reactance. This would be considered to be a typical response of a good carbon composition resistor.

The resistors removed from the T4 give a different response. When a bad resistor is measured using the same test procedure, a markedly different result is obtained. The following example (figure 6) refers to a 20 ohm resistor and shows it's reactance and resistance as a function of frequency.

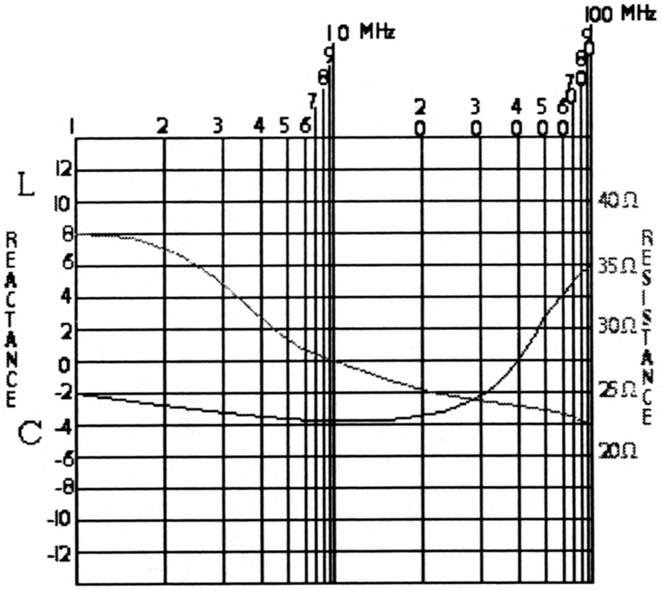
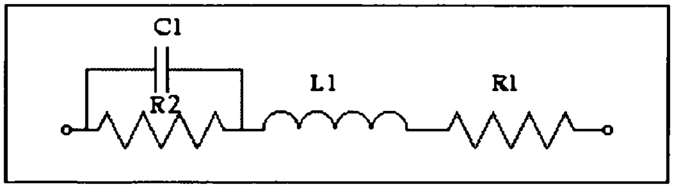


Figure 6

In figure 6 it can be seen that the reactive component of the resistor is capacitive until the frequency rises through 40MHz. The DC resistance is only 37.5 ohms for the extreme low end of the frequency band (less than 1MHz). Not until the frequency is above 40MHz does the resistor's reactivity become inductive.

From these findings, it was determined that the carbon composition resistors being used have become, in themselves, a somewhat complex reactive circuit (see figure 7).



Resistor equivelancy circuit.

Figure 7.

In figure 7, R1 again represents the actual DC resistive value of the resistor. Similarly, L1 represents the inherent inductance. C2 represents some stray capacitance and R2 represents a secondary resistive component.

When the DC resistive value of the resistors change (R1), the other inherent reactive and resistive values (C1,L1,&R2) also appear to change. Curiously, the reactive changes of these simple resistors are not necessarily coincident with their DC resistive changes.

Whereas the stray capacitance (C1) inherent to the resistors can be measured, and the reactance that this capacitance offers does change as a function of frequency, it remains unclear why the actual capacitive value of the resistor seems to change as a function of frequency.

It has yet to be determined what single phenomena is responsible for the unusual reactive behavior displayed by the resistors in the 'T' attenuation networks. It is assumed that some chemical reaction between the resistive carbon and the conductors used in the physical construction of the resistor may be responsible for this behavior. Another, if rather undesireable possibility, is that the condition was pre-existing in some of these resistors and simply remained undetected until now.

It is important to note, however, that none of this unusual reactive behavior has been displayed by any new carbon composition resistors. Only those taken out of the T4s 'T' attenuation networks (due to high DC resistive readings) have been found to have these peculiar reactive properties.