Wideband Microstrip Ungrounded Load

This paper describes a novel ungrounded termination suitable for MIC and MMIC applications that can be designed with the aid of simple design curves. Consisting of a lossy resonant ring it gives 20dB return loss bandwidth of 70 percent or more.

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Microwave systems often require the use of resistive loads as terminations for directional couplers, isolators, fixed attenuators, power dividers and switches. In both MIC and MMIC media the necessary ground connection for the termination can be achieved either by direct grounding or by virtual grounding.

Direct connection of a load to ground is a lumped element approach yielding broad bandwidth at low frequencies but high frequency limits due to the grounding conductor's inductance.

Direct connection results in a wideband termination, since it is effectively a lumped element approach. However, it is limited, due to the inductive length of the ground connection, to frequencies below about 10 GHz. It has the additional disadvantage of requiring either via-holes in the substrate or ground strap placement at the substrate edge.

Virtual grounding, in contrast, relies on the capacitive coupling through the substrate to ground to achieve an effective RF ground. Numerous techniques for virtual grounding have been developed, such as the quarter-wave open circuit resonant stub and the quarter-wave resonant radial line stub. However, these tend to be limited in bandwidth (less than 60%), are large in size, and, because they are radiating structures themselves, can cause unwanted coupling to other parts of the circuit.

Direct connection of a lelies on the capacitive coupling through the MIC substrate to ground, offering higher frequency operation and manufacturing simplicity.

Recently, broadband planar non contacting terminations have been reported by Linner and Lunden [1] and by Giannini and Ruggeiri [2]. Linner and Lunden reported theoretical 20 dB return loss bandwidths of up to 160%. However, their approach requires transmission lines of very high and low impedances which are neither suitable for accurate CAD analysis nor amenable to microstrip realization. Giannini and Ruggieri reported a 20 dB bandwidth of 120% using radial stubs, but radial stubs are not simple to model and are accordingly difficult to design accurately for such wide bandwidths.

This paper describes a structure, design techniques and experimental results for a novel termination which overcomes the shortcomings of previous non-contacting terminations. It has improved bandwidth, requires little design effort and is amenable to microstrip manufacturing. It is best described as a "lossy resonant ring" structure.

The Single Lossy Resonant Ring Termination

The simplest structure for the lossy resonant ring termination is shown schematically in Figure 1. It is formed by cascading two resistors R1 and R2, the latter of which has a parallel connected transmission line of characteristic impedance Z2 that is a half wavelength long at the desired center frequency of operation of the termination.

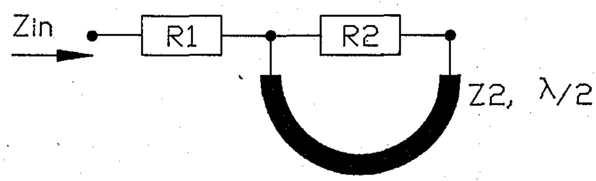

Figure 1. Schematic diagram of the single lossy resonant ring termination.

Measured and calculated results are in close agreement, illustrating the design simplicity of the approach.

The ideal values for R1, R2 and Z2 have been determined by using an ideal element CAD optimizer, which is set to realize the required return loss and bandwidth. This approach can be used specifically for any given application. Alternatively, the results of this optimization for various percentage bandwidths at 4 GHz are shown in Table 1. The results are shown graphically in Figures 2 and 3 for design convenience, along with the design parameters for a double lossy resonant ring termination described later.

% Bandwidth @ 4 GHz	R_1 [Ω]	R_2 [Ω]	Z_2 [Ω]
125	46.5	49	20
110	43	66	30
90	33	107	50
80	22	148	70
75	13	187	90
65	4	226	110

Table 1. Single lossy resonant ring parameters from CAD optimization.

The 75% bandwidth termination was selected for analysis and optimization on a CAD program, before being manufactured in a totally planar MIC environment using tantalum-nitride (TaN) thin film resistors on a 0.635 mm (25 mil) thick alumina (Er = 9.8) substrate.

Optimization was a necessary step in order to take into account the non-ideal microstrip charac-

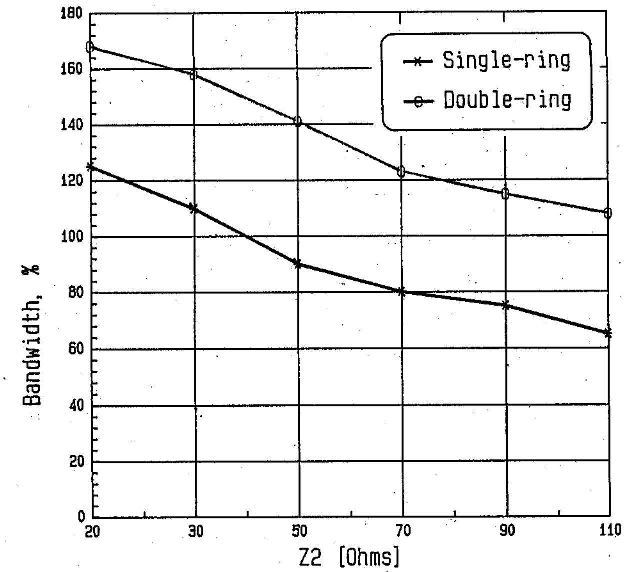

Figure 2. Design curve for bandwidth and line impedance selection.

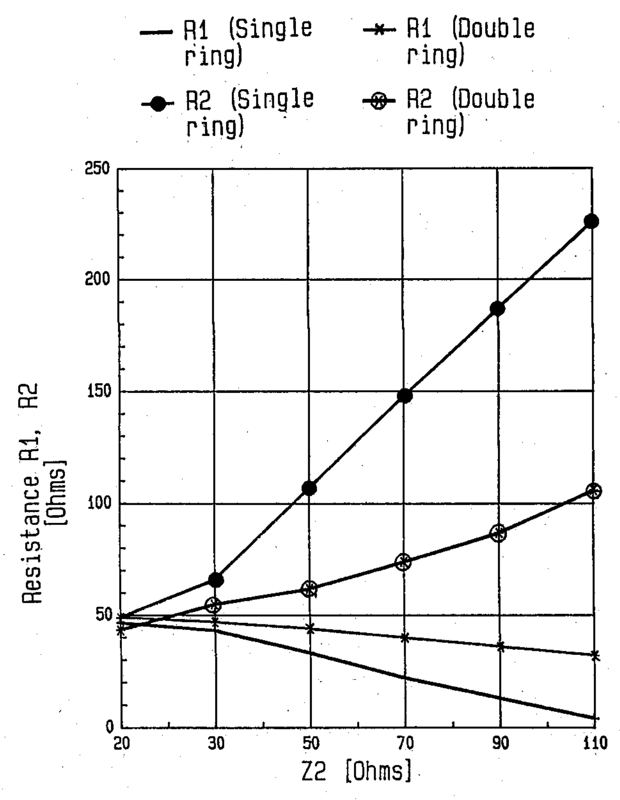

Figure 3. Design curve for resistances, R1 and R2, selection.

teristics of the termination. Figure 4 is a photograph of the resulting termination, the measured characteristics of which are shown in Figure 5 along with the predicted values.

Figure 4. Photograph of the single lossy resonant ring termination on 25 mil thick alumina substrate.

The termination achieves a 72% bandwidth near 4 GHz over which the return loss is below 20 dB. Furthermore, the measured and calculated results are in close agreement.

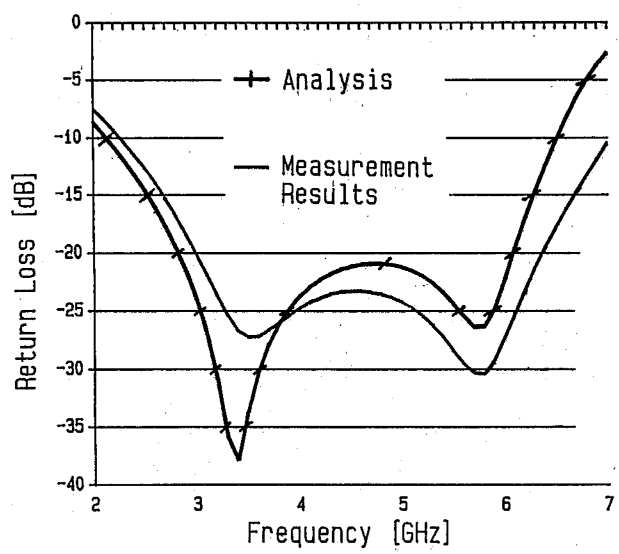

Figure 5. Predicted and measured return loss of the single lossy resonant ring.

The lossy resonant ring ground is readily designed using a CAD optimization routine.

The required impedances for the theoretical 75% bandwidth termination represent nearly the practical limits of MIC thin film technology. Therefore it is expected that the wider bandwidth terminations of this type are better realized using the double resonant circuit described next.

Wider operational bandwidths can be obtained using stagger tuned multiple resonant ring circuits.

The Double Lossy Resonant Ring Termination

A simple extension of the single lossy resonant ring leads to the structure shown in Figure 6, wherein two resonant rings are paralleled. Each has a different resonant frequency offset from the desired operating center frequency in order to achieve a net bandwidth wider than what can be accommodated by a single resonant ring.

Table 2 is a listing of the theoretical parameters acquired using a similar CAD analysis. For this design a 141% bandwidth was used for the optimization. The subsequent fabrication was also performed on a 25 mil alumina substrate with TaN thin film resistors.

% Bandwidth @ 8 GHz	R_1 [Ω]	R_2 [Ω]	Z_2 [Ω]
168	49	43.5	20
158	47	55	30
141	44	62	50
123	40	74	70
115	36	87	90
108	32	106	110

Table 2. Double lossy resonant ring parameters from CAD optimization.

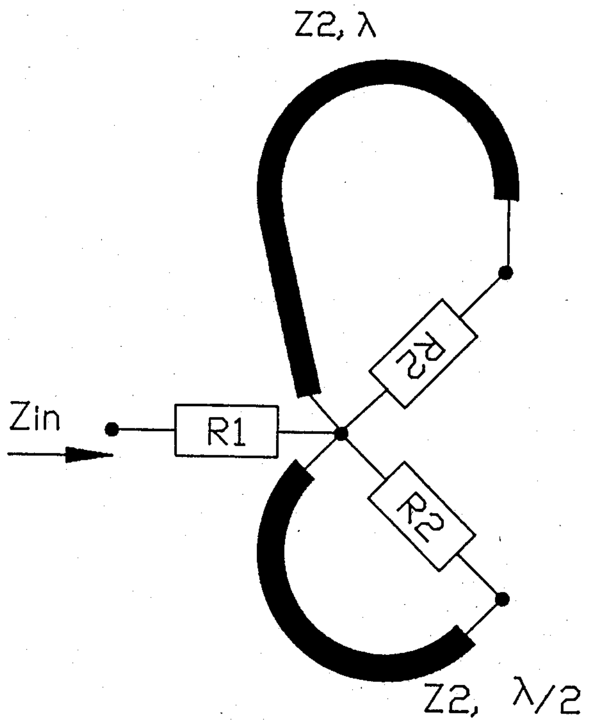

Figure 6. Schematic diagram of the double lossy resonant ring termination.

The analysis included the inter-ring proximity coupling, which was expected to be significant from the layout chosen (Figure 7). If the rings were angled at 45 degrees to one another, a better resonance in the return loss characteristic would be expected.

A 20 dB return loss bandwidth of 137% was realized using the double ring at 8 GHz.

The actual termination achieved a 20 dB bandwidth at 8 Ghz of 137% (Figure 8.), and at the same time showed good correlation with the CAD optimized, theoretical result once the parasitic elements of the circuit were included.

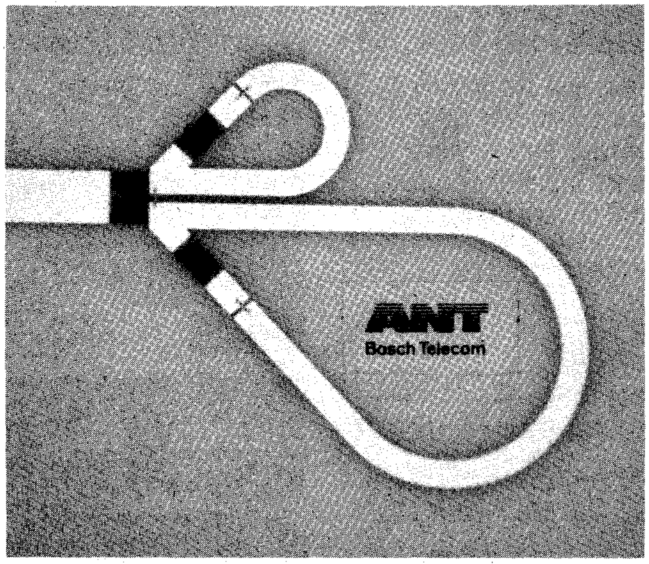

Figure 7. Photograph of the double lossy resonant ring termination.

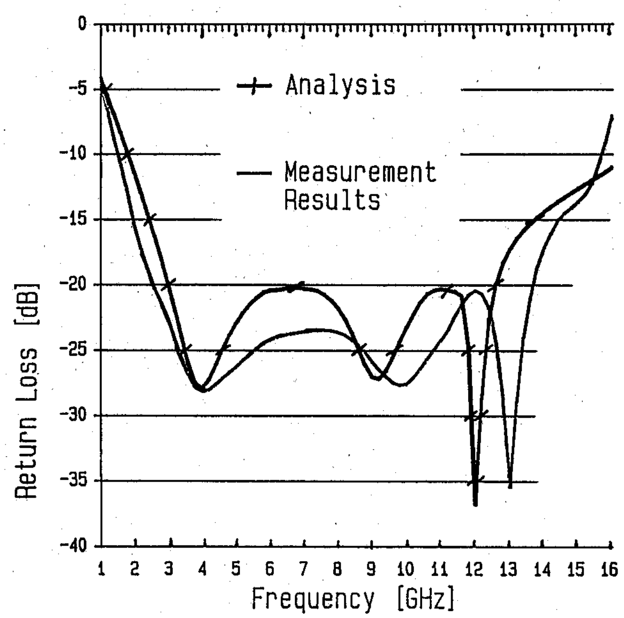

Figure 8. Measured and calculated performance of the double ring termination.

Still wider bandwidth should be achievable using three resonant rings, having respective lengths of a quarter, a half and a full wavelength. Preliminary CAD analysis suggests that such a design centered at 5 Ghz could operate with a 0.5 to 30 GHz simultaneous bandwidth.

References

1. Linner, J. P. and Lunden, H. B., "Theory and design of broadband non-grounded matched loads for planar circuits," IEEE MTT Transactions, Vol. MTT-34, pp. 892-896, August 1986.
2. Giannini, F. and Ruggieri, M., "A broadband termination utilizing multiple radial line structure," MIOP Proceedings, Volume 2, No. 6B1, Wiesbaden, FRG, 1987.

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