Wide-Band Ground-Plane dc Block and Bias Feed

THOMAS E. KOSCICA

Abstract —**The realization of a new wide-band ground-plane dc block and bias feed is described for microstrip transmission lines operating in *Ka*-band, 26.5–40.0 GHz. The waveguide-to-microstrip fixture and transition used for testing are described. Analysis of the ground-plane bias gap structure is provided. A few possible applications are discussed.**

I. Introduction

Microstrip circuits often require voltage offsets for biasing devices. To implement such biasing, the circuit designer needs a method which dc isolates sections of a circuit that are at different potentials while minimally reducing a transmitted signal's energy. To apply an offset potential, an attached bias feed is needed that passes dc voltages to the circuit and blocks signal energy from escaping. At low frequencies, dc isolation is achieved using lumped-element capacitors while lumped inductors are used in bias feed lines. At the *Ka*-band of frequencies, 26.5–40.0 GHz, microstrip circuits can be offset biased using a quarter-wavelength dc block combined with a low-pass filter network acting as a bias feed, both of which are located in the circuit's top plane. There are several reports in the literature on these and similar low-loss transmission line components achieving wide-band performance [1]–[5].

This paper reports on the development of a full *Ka*-band dc block and bias feed embedded in the ground plane of a microstrip circuit. The structure is a new full-band circuit element for use in microstrip designs.

II. Test System

To perform the required microstrip testing, a full-band waveguide-to-microstrip transition and a support fixture are needed. The fixture used to hold the transition in the current work is shown in Fig. 1. The only physical connection between the two transition fixtures used for insertion loss testing is the microstrip circuit itself. This approach allows microstrip ground-plane structures to be free from interactions with a support fixture.

Building on the work of others [6], [7], a waveguide-to-microstrip transition, shown in Fig. 2, was designed to give low loss. The combined transmission loss for two transitions on Duroid (dielectric constant = 2.2) separated by 0.75 in of 0.020-in-wide conductor is 0.8–1.2 dB across the waveguide band.

III. Design Method

A low-loss ground-plane dc blocking structure needs to satisfy a few design rules. To begin with, the E-field and H-field components must pass unimpeded across the dc blocking structure. Simultaneously, the bias gap must not provide resonant modes into which signal energy could be coupled and lost.

To meet the first condition, the ground plane is chosen wide enough (Fig. 3(a)) so that the E field and H field are confined to the top side of the microstrip with a minimum amount of fringing fields wrapping around the ground plane. Then by

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The author is with the Electronics Technology and Devices Laboratory, U.S. Army LABCOM, Ft. Monmouth, NJ 07703.
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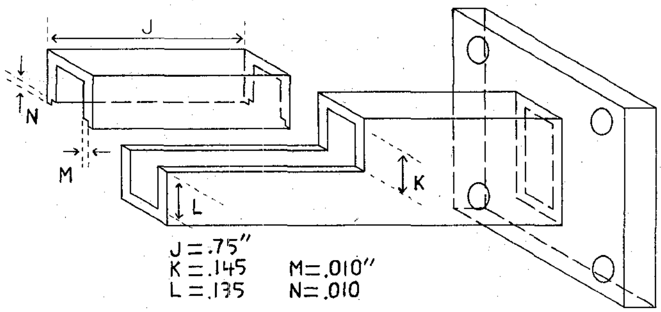


Fig. 1. *Ka*-band (26.5–40.0 GHz) waveguide to microstrip fixture. Surrounding alignment clamp is not shown.

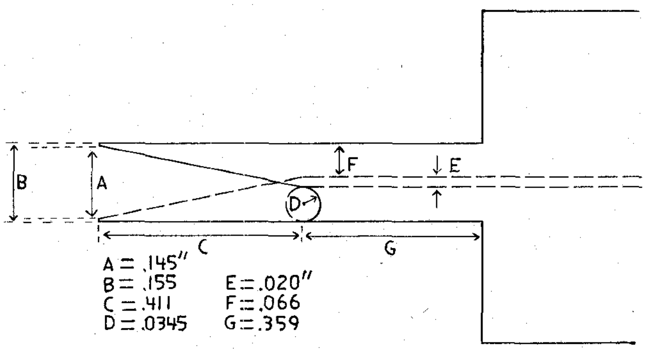


Fig. 2. *Ka*-band waveguide to microstrip transition.

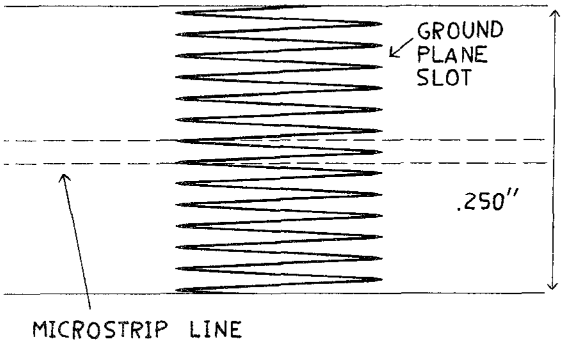
including enough distributed capacitance in the ground-plane dc block and by operating within a nonresonant frequency range (discussed below) of the bias gap structure, the displacement current, or D field, flowing across the gap is sufficient to allow the E-field and H-field components to pass with little reflection.

To understand and control the resonant modes introduced by the sawtooth dc block design, it is necessary to realize that energy is coupled into the structure in a slotline mode. The periodic structure of the slotline then determines the location of resonances.

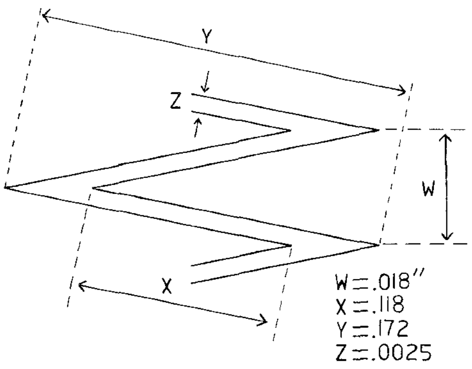
Exploring the behavior of a simple slot resonator gives some insight into the proper design approach of the ground-plane dc block. Three issues concerning basic slot resonators are of interest in the present case: orientation angle with respect to the propagating signal, slot length, and slot width.

As shown in Fig. 4, the steeper the angle between the slot and the wave propagation direction, the larger the E-field component coupled across and into the resonator. This implies that to couple the minimum amount of energy into the dc block, the slotline sections in the structure should have small angles with respect to the signal propagation direction.

The length of a basic slot resonator controls the resonant frequencies at which energy will be strongly absorbed. The slot length corresponds to a half-wave for the fundamental resonance. Experimental testing of the dc block shown in parts (a) and (b) of Fig. 3 reveals that there exists a resonance dropout just outside the *Ka*-band at both the low and high frequency ends. It is found that the above-band mode depends more on length x while the below-band resonant mode depends more on length y in the figure. To approximately locate the modes, use the effective dielectric constant in slotline and calculate the



(a)



(b)

Fig. 3. (a) Overview of the microstrip line with the ground-plane dc block tested in the current work. (b) Detail of slot dimensions used in the current work, these repeat throughout the ground-plane structure.

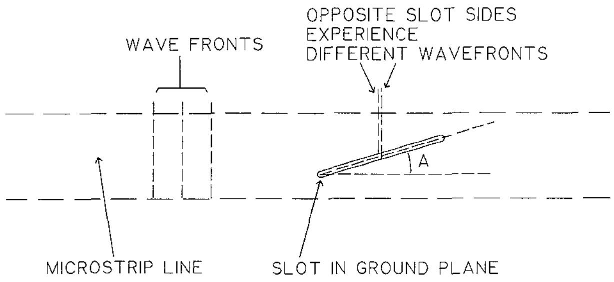


Fig. 4. As angle A is increased, both the net E field coupled across the slot resonator and the impedance disturbance in the transmission line due to the slot increase.

distance x or y from the half-wavelength corresponding to the desired upper and lower passband dropout. More accurate predictability awaits modeling of the periodic slotline.

For a simple slot resonator, enlarging the width has several effects on performance, including increased coupling of energy from the transmission line to the slot and increased radiation loss of energy from the slot. Both the width of the slot's resonance dropout and the phase performance across frequency are affected. Since the orientation angle and lengths x and y of Fig. 3(b) are constrained by the above requirements on positioning the resonances out of the passband, width adjustment is not an independent parameter.

Using the above observations allows for an informed, empirical search for a low-loss design. The design in this paper achieves a loss of approximately 0.1–0.5 dB over the full *Ka*-band.

It is of interest to know how the dc block performs when materials are brought in proximity to the ground plane where the structure is located. Performance is minimally affected if metal or other objects are placed beyond 0.25 in of the dc block on the ground-plane side. Materials placed nearer to the ground-plane bias gap can slightly shift resonant modes to lower frequencies. Note that use of the dc block in a circuit would require a clearance channel beneath the structure which, furthermore, must act as a dc insulator.

IV. Bias Feed

A circuit which is dc isolated by the ground-plane block can be offset biased without the additional degradation which occurs in conventional top-conductor bias feeds. Two conditions are needed. First, the ground plane must be of sufficient width to confine essentially all the signal energy to the top side of the microstrip; second, the ground plane must be several skin depths in thickness. With these conditions met, it is then possible to connect the bias line to the back side of the ground plane such that dc is applied without any RF energy leakage. This method of biasing allows a high degree of RF isolation between the circuit and the bias line.

V. Applications

The resulting full-band dc block and bias feed arrangement can find use in various applications.

The dc isolated ground can allow some biasing arrangements not previously possible. It is possible to simplify power supply requirements in circuits which otherwise would require several voltage levels because of a common circuit ground, e.g., certain varactor-tuned oscillator designs. Also, circuits that have completely floating/independent power supplies can now be constructed if the ground-plane block is used in conjunction with a top plane quarter-wave bias gap. Use of completely floating supplies allows the separation of low-frequency feedback effects between stages due to power supply loading during operation. In addition, full dc isolation effectively breaks ground loops which can couple low-frequency noise into a system.

VI. Summary

All in all, the dc block and bias feed reported on in this paper provide a new option for *Ka*-band circuit design. Using appropriate scaling and some empirical fine-tuning should allow similar wide-band performance in neighboring frequency bands.

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