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EQUIVALENT CIRCUIT OF A KUROKAWA-TYPE WAVEGUIDE POWER COMBINER

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ABSTRACT

An analysis is carried out for a two-post Kurokawa-type waveguide power combiner structure, using an image theory approach, which models not only the two individual components but also the cross-coupling between the two adjacent posts. Comparison with experimental measurements shows that the basic theory as applied to the single-post case remains accurate for the practical case of the post close to the waveguide sidewall.

INTRODUCTION

The two-post coaxial-line/rectangular-waveguide cross-coupled structure shown in Figure 1 forms the basic module of the Kurokawa-type power combiner [1] which has been used by many workers[2,3,4] to combine the power of two or more solid-state sources.

There is a need for an accurate equivalent circuit of the waveguide power combiner to facilitate design optimisation. Such an equivalent circuit can be used to maximise power output or tuning range, and to avoid circuit instabilites. It would also allow a systematic study of the effect of circuit dimensions, circuit losses, coaxial mismatch terminations and waveguide tuning on power combiner performance.

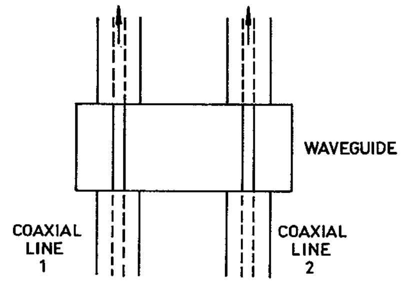
The equivalent circuits presented so far[5,6,7] for this type of power combiner have all neglected the cross-coupling between the adjacent posts in the same waveguide transverse plane, and have hence neglected the interaction between the solid-state sources normally placed at the end of the coaxial lines. Furthermore they have used a simplified equivalent circuit for the single-post structure itself. This shortcoming was overcome by the work of Allen, Bates and Khan [8] , presented at the 1982 International Microwave Symposium. That paper gave an accurate equivalent circuit for the single-post mount.

This paper sets out the extensions to the theory to include the two-post structure of Figure 1, which includes the interaction between the adjacent posts. This will allow the analysis of a two-diode power combiner, to include circuit optimisation and source interaction.

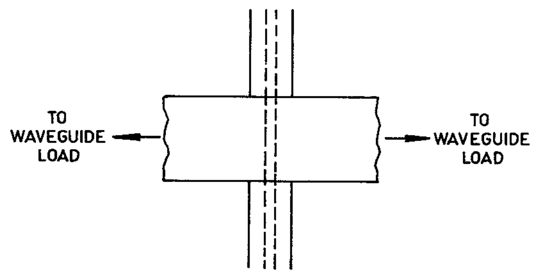
STRUCTURE AND APPROACH

The structure being modelled is shown in Figure 1. It consists of two coaxial lines in the same transverse plane cross-coupling to rectangular waveguide near the sidewall. Sources such as IMPATT diodes are normally placed at the bottom of the input coaxial lines to excite the structure. The output coaxial lines are usually terminated by matched microwave absorbers.

Because the coaxial line is situated very close to the sidewall it was necessary to verify that the basic single-post theory presented previously[8] was still accurate at this extreme position where the close waveguide sidewall might be expected to have an effect. This verification is provided by the measurements shown in Figures 2-4. The measured values taken using a computer-corrected measurement system are compared to the model with the coaxial line at the very edge of the guide, for both a short circuit and a matched load on one waveguide arm, and for varying frequency and short circuit position. The agreement is very good, and is much better than any previously published model at this coaxial position.



(a) CROSS SECTION



(b) SIDE SECTION

Figure 1: The two-device Kurokawa-type power combiner structure.

With the accuracy of the single-post model verified, a general analysis is carried out for the two-post combiner structure by extension of the image theory approach used previously[8] which is based on the fundamental field theory studies of Williamson[9,10]. The input coaxial lines are represented by a magnetic current frill situated in the coaxial aperture plane, which is proportional to the TEM-mode electric field in the coaxial lines. The analysis is initially simplified by considering the output coaxial lines to be short circuited at the coaxial aperture plane.

Image theory is then applied to the two posts in guide structure which results in an image set as shown in Figure 5. This consists of two sets of images, one for each coaxial line. The effect of this second set of images as seen by the first coax gives rise to the cross-coupling between the posts. The input admittance

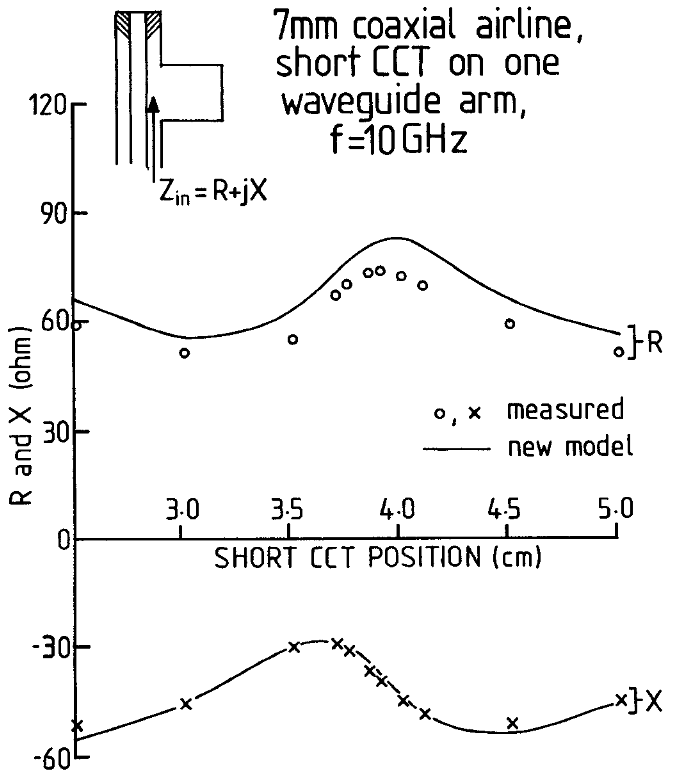


Figure 2: Input impedance of the single-post mount, as a function of the short circuit position on one waveguide port, and matched terminations elsewhere.

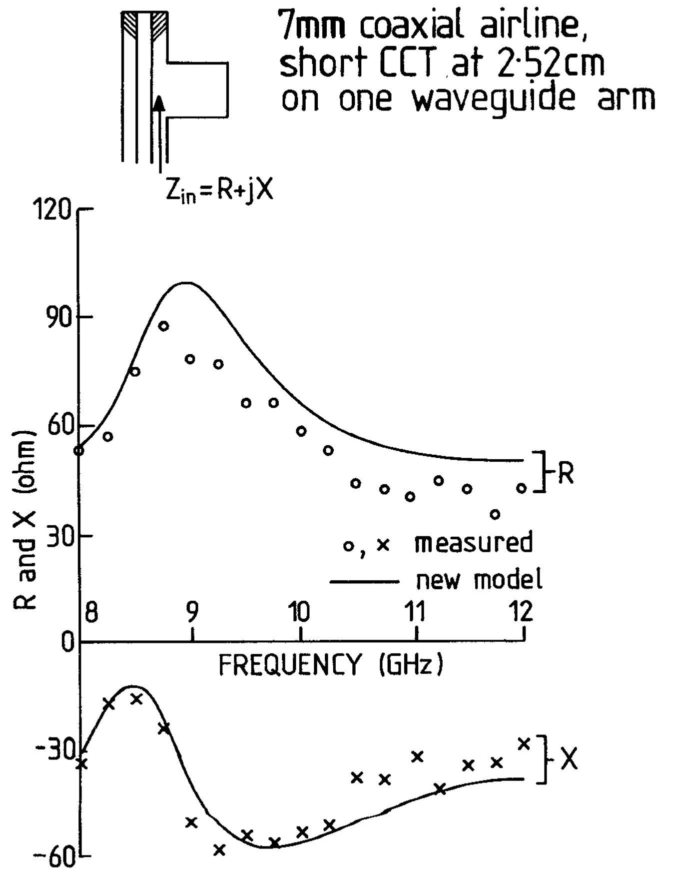


Figure 3: Input impedance of the single-post mount as a function of frequency, with a fixed short circuit on one waveguide port, and matched terminations elsewhere.

seen from either one of the coaxial lines is calculated from the summation of these images with the appropriate boundary conditions applied. The resulting admittance contains two sets of series, representing the two sets of images shown in Figure 5, with one set for each waveguide post; the first set represents the contribution of the post to its own input admittance (as in [8]), and the second set represents the contribution of the other post to the admittance. Hence the second set represents the cross-coupling component. The resulting admittance is given by the equation:

$$Y = -F\left\{\ell n\frac{b}{a} + \frac{\pi}{2}F_1(A,B)\left[\frac{Jo(B)}{Jo(A)} + j\frac{F_1(A,B)}{Jo(A)S_2^*(A,D,E)}\right]\right.$$

$$-2\sum_{m=1}^{\infty}\frac{1}{q_m^2}\left[\ell n\frac{b}{a} + F_2(q_mB,\ q_mA)\,.\right.$$

$$\left.\left.\cdot\left[\frac{Io(q_mB)}{Io(q_mA)} + \frac{F_2(q_mB,q_mA)}{Io(q_mA)S_2(q_mA,q_mD,E)}\right]\right]\right\}$$

where F,a,b,A,B,D,E,q_m are functions of frequency and circuit dimensions, and $F_1()$, $F_2()$ are functions of Bessel functions, and S_2, S_2* contain series of Bessel and Hankel functions. The expressions are not written out in full here because of space limitations. The infinite series contained in this equation are slowly converging but it is possible to transform them into a more rapidly converging form.

The effect of the output coaxial lines on the admittance can be determined by superposition as was done for the single-post case. The admittance expression may be manipulated into an equivalent circuit form as shown in Figure 6 by considering only one propagating waveguide mode.

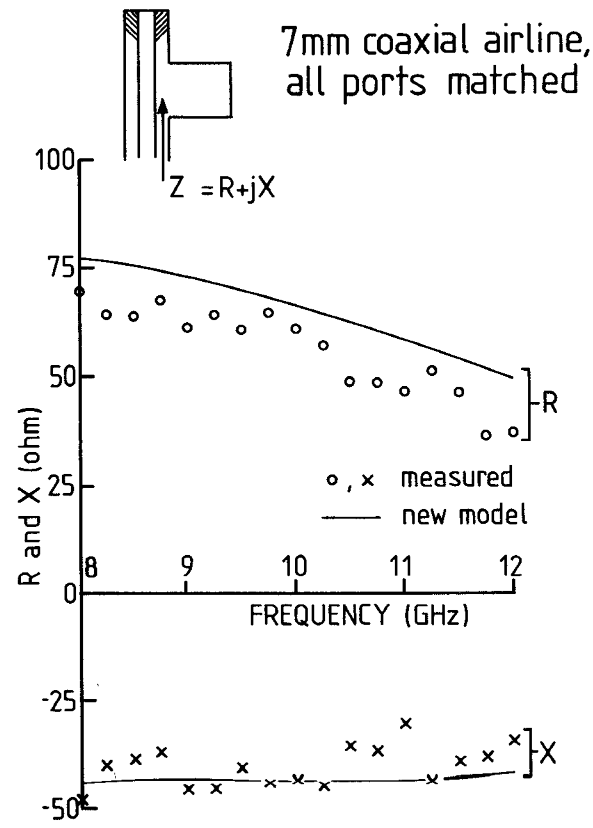


Figure 4: Input impedance of the single-post mount, as a function of frequency, with matched terminations on all output ports.

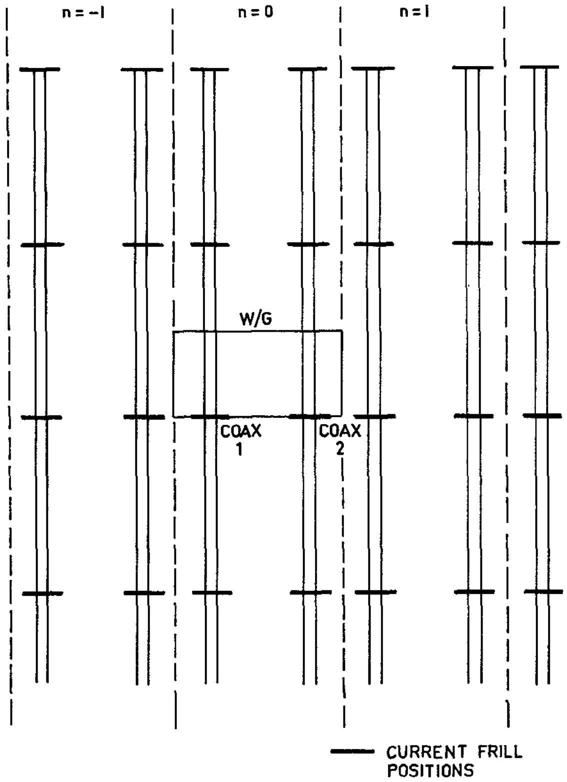


Figure 5: Image set arising from two-post combiner structure in rectangular waveguide.

CONCLUSION

A general analysis procedure has been presented which produces a model of the two-post Kurokawa-type power combiner, that for the first time includes the effect of the cross-coupling between the adjacent posts. The basic elements of the theory for the single-post case are shown to be accurate for the practically important case of the post near the waveguide sidewall by comparison with measurements. This model now provides a means for systematic study of the two-source combiner when used with a nonlinear oscillator analysis procedure such as that of Bates and Khan[11]. It also points the way for modelling of multi-device combiners having more than two devices.

ACKNOWLEDGEMENTS

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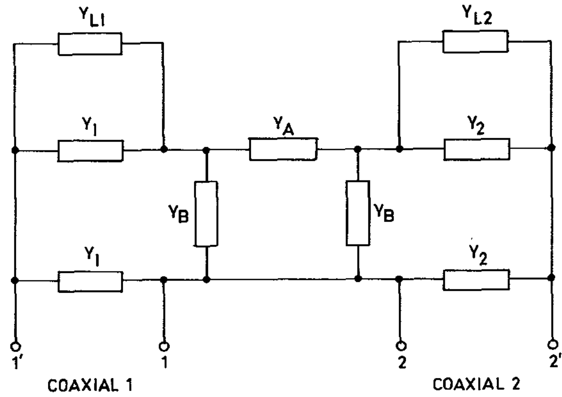

Figure 6: A general equivalent circuit of the two-post Kurokawa-type combiner structure.

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