PRACTICAL REALISATION OF DIFFICULT MICROSTRIP LINE HYBRID COUPLERS AND POWER DIVIDERS

H. Ashoka

MITEC Ltd, Seventeen Mile Rocks, AUSTRALIA

ABSTRACT

Microstrip line asymmetrical branch-line couplers, Wilkinson power dividers, and rat race hybrids with coupling values and division ratios that are almost unrealisable using conventional techniques, have been realised using impedance - and admittance inverters with practical microstrip line dimensions. Experimental results for some extreme examples are given.

INTRODUCTION

Applications such as phased array systems and beam forming networks require unequal power dividers and hybrids, usually with very tight or very loose coupling values and division ratios. Conventional microstrip line branch-line couplers with such coupling values are difficult to realise in practice as they require transmission lines with very low or very high characteristic impedances. Rat race hybrids and Wilkinson power dividers require very high impedance lines for high power split ratios as well.

The line widths for low impedance microstrip lines become too wide and for high impedance microstrip lines the line widths become too narrow which cause higher order mode and fabrication problems respectively. Thus these conventional devices are limited in coupling values from about 3 dB to 8 dB.

In this paper, a technique developed to overcome the disadvantages of the conventional branch-line coupler in this respect [1,2] has been used to build the difficult couplers and power dividers.

THE NEW TECHNIQUE

The new technique involves replacing the quarter wave long lines of the conventional devices with the general types of impedance inverters or admittance inverters [1,2]. The general forms of impedance (or K) and admittance (or J) inverters are shown in figure 1a and figure 1b respectively along with their design equations [3]. The impedance inverter is used to replace any low impedance quarter wave long lines and the admittance inverter is used to replace any high impedance quarter wave long lines. These inverters can be designed with suitable line impedances such that the lines are easily realised on any substrate.

Four examples of difficult couplers and dividers are given below to illustrate the advantages of the present method. All the examples given below were designed for a 50 Ω system and realised on 0.5 mm thick substrates with $\epsilon_r = 2.2$. Computer-aided design software TOUCHSTONE was used to optimise the calculated performance in each case. The measured results include the losses in microstrip to SMA adapters, SMA to APC7 adapters and bends totalling about 0.4 dB.

BRANCH-LINE COUPLER WITH TIGHT COUPLING

A conventional branch-line coupler with -1 dB at the coupled port (-6.9 dB at the through port) is shown in figure 2 [4] where Z_{01} = 22.7 Ω and Z_{02} = 25.5 Ω. These low impedance lines are replaced by impedance inverters with K = 22.7 and K = 25.5 respectively in the new technique. The inverters are realised with X_a set to zero, Z_0 = 50 Ω, and X_b implemented by an open circuited line with characteristic impedance of 35 Ω, both of which are more practical lines in microstrip. The choice of 50 Ω and 35 Ω lines was arbitrary and any other convenient values could well be chosen, indicating the flexibility of this design method. The physical realisation of the new 1 dB branch-line coupler and the measured performance at 5 GHz are shown in figure 3.

BRANCH-LINE COUPLER WITH LOOSE COUPLING

A conventional branch-line coupler with -10 dB at the coupled port (-0.46 dB at the through port) has Z_{01} = 47.4 Ω and Z_{02} = 150 Ω referring to figure 2. The 150 Ω shunt arm lines are difficult to realise and these are replaced by admittance inverters with J = (1/150) = 6.67 mS. The admittance inverters are realised with Y_0 = 14.3 mS (or Z_0 = 70 Ω), B_a set to zero, and B_b implemented by a series inductance of 4 nH which takes the form of a short length of thin wire. This inductance can also be realised in printed circuit form.

The physical realisation of the new 10 dB branch-line coupler at 5 GHz and the measured performance are shown in figure 4. The inductance of 4 nH was realised by a loop of wire of 0.18 mm diameter and loop diameter of 3 mm.

WILKINSON POWER DIVIDER

A conventional Wilkinson power divider with 4 to 1 power split ratio (-0.97 dB at one output port and -7 dB at the other) is shown in figure 5 [4] where Z_{01} = 158 Ω, Z_{02} = 39.5 Ω, Z_{03} = 70.7 Ω, Z_{04} = 35.4 Ω, and R = 125 Ω. The 158 Ω line is difficult to realise and is replaced with an admittance inverter realised at 5 GHz with Y_0 = 14.2 mS (or Z_0 = 70.7 Ω), and B_b implemented by a 4.03 nH inductance. The physical realisation of the new

IF1

unequal Wilkinson power divider and the measured response are shown in figure 6.

RAT RACE HYBRID

A conventional modified rat race hybrid with 10 dB output power split ratio (-0.41 dB at one output port and -10.41 dB at the other) is shown in figure 7 [4] where $Z_{01} = 52.4\ \Omega$ and $Z_{02} = 165.8\ \Omega$. The 165.8 Ω high impedance lines are replaced by admittance inverters realised at 5 GHz with 70.7 Ω lines and 4.4 nH inductances. The physical realisation of the new rat-race hybrid and the measured performance are shown in figure 8.

It is seen from figures 3, 4, 6, and 8 that the new implementation of these difficut couplers and power dividers provides excellent power division, isolation, return loss response while greatly simplifying the design and fabrication. In all of the above examples, the measured phase response was within ± 5° of the theoretical values over a 8 percent bandwidth.

CONCLUSIONS

Asymmetrical branch-line couplers, Wilkinson power dividers, and rat race hybrids with coupling values and division ratios almost unrealisable using conventional microstrip line techniques, have been realised with practical microstrip line dimensions using impedance - and admittance inverters. Experimental results have been presented for some extreme examples. The designer has the choice of many suitable microstrip line dimensions to realise the inverters.

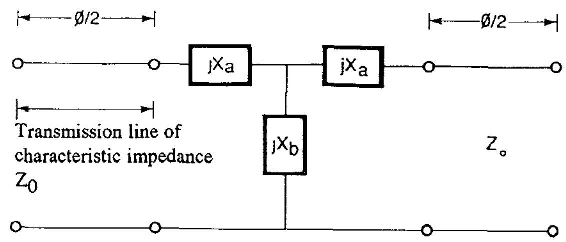
REFERENCES

1. H.Ashoka, "New Type of Branch-line Hybrids", Proc. European Microwave Conf., pp.785-790, Stockholm, 1988.

2. H.Ashoka and A.M.Khilla, German Patents No.3740098 and No.3740099.

3. G.L.Matthei, L.Young, and E.M.T.Jones, Microwave Filters, Impedance Matching Networks and Coupling Structures, McGraw-Hill, New York, 1964, pp.434-440.

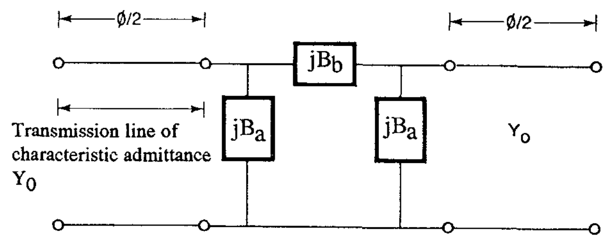
4. V.F.Fusco, Microwave Circuits - Analysis and Computer-aided Design, Prentice-Hall International (UK) Ltd, London, 1987, pp.316-332.



$$K = Z_0 \mid \mathrm{Tan}\,(\phi/2 + \mathrm{Tan}^{-1} X_a/Z_0) \mid$$

$$\phi = -\mathrm{Tan}^{-1}(2X_b/Z_0 + X_a/Z_0) - \mathrm{Tan}^{-1}(X_a/Z_0)$$

Figure 1a. Impedance inverter and its design equations.



$$J = Y_0 \mid \mathrm{Tan}\,(\phi/2 + \mathrm{Tan}^{-1} B_a/Y_0) \mid$$

$$\phi = -\mathrm{Tan}^{-1}(2B_b/Y_0 + B_a/Y_0) - \mathrm{Tan}^{-1}(B_a/Y_0)$$

Figure 1b. Admittance inverter and its design equations

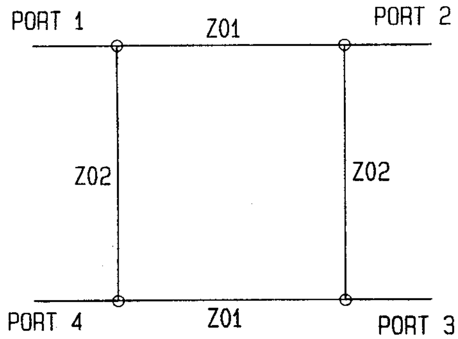


Figure 2. Conventional branch-line coupler

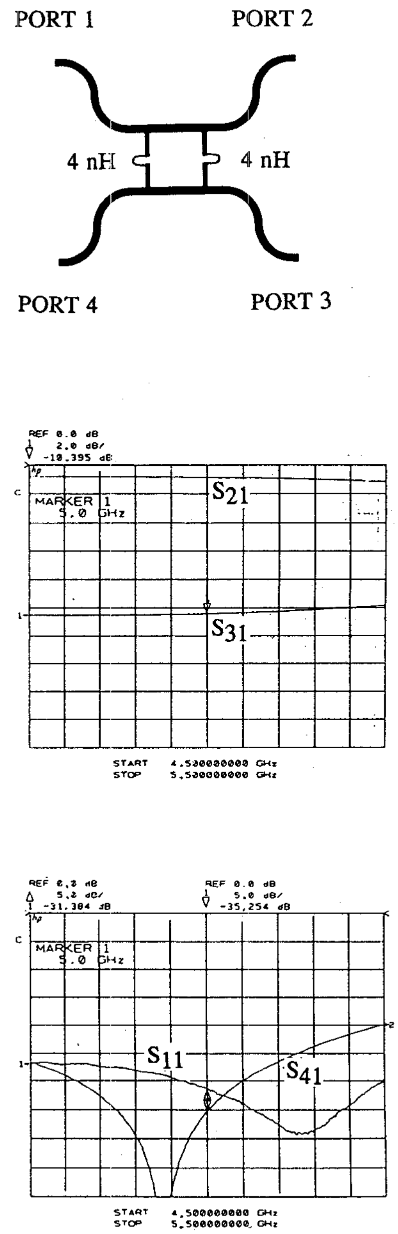


Figure 4. Physical realisation and measured performance of the 10 dB branch-line coupler.

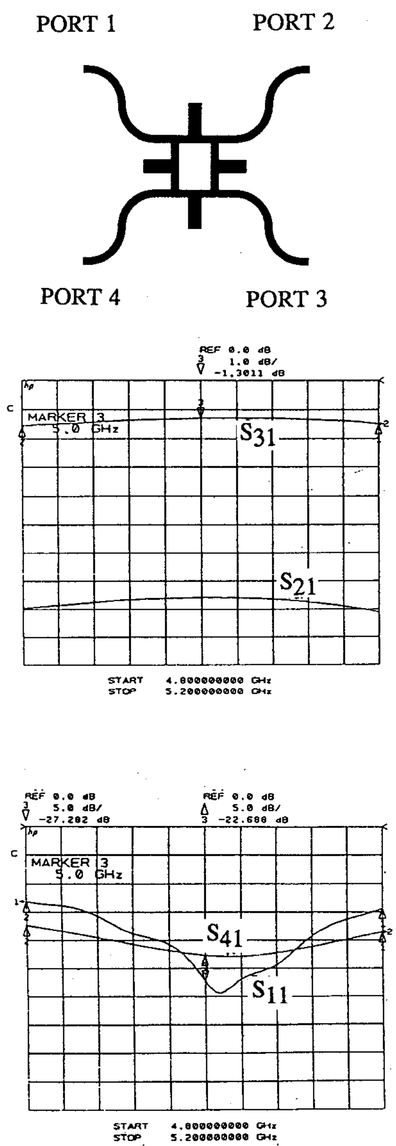


Figure 3. Physical realisation and measured performance of the 1 dB branch-line coupler.

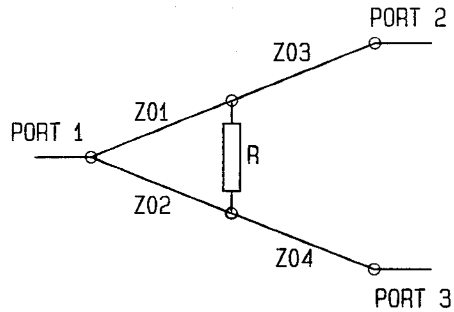


Figure 5. Conventional Wilkinson power divider with unequal output power split.

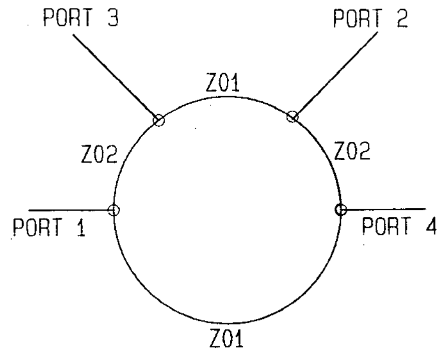


Figure 7. Conventional modified rat-race hybrid.

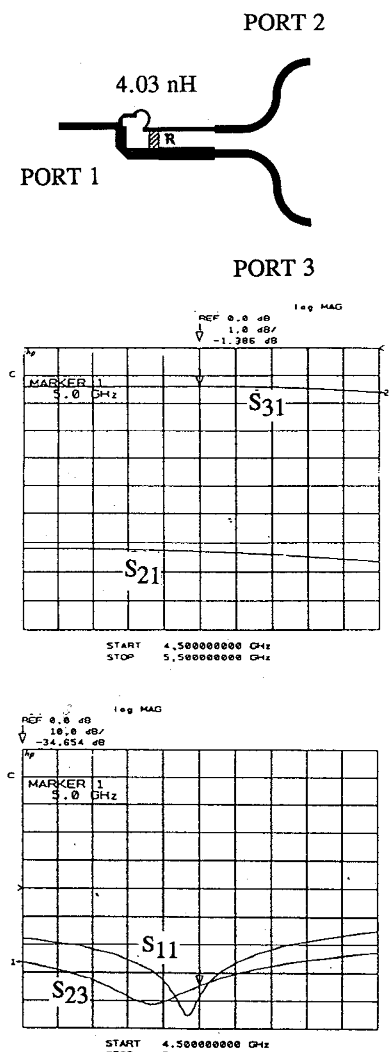


Figure 6. Physical realisation and measured performance of the Wilkinson power divider with 4:1 output power split ratio.

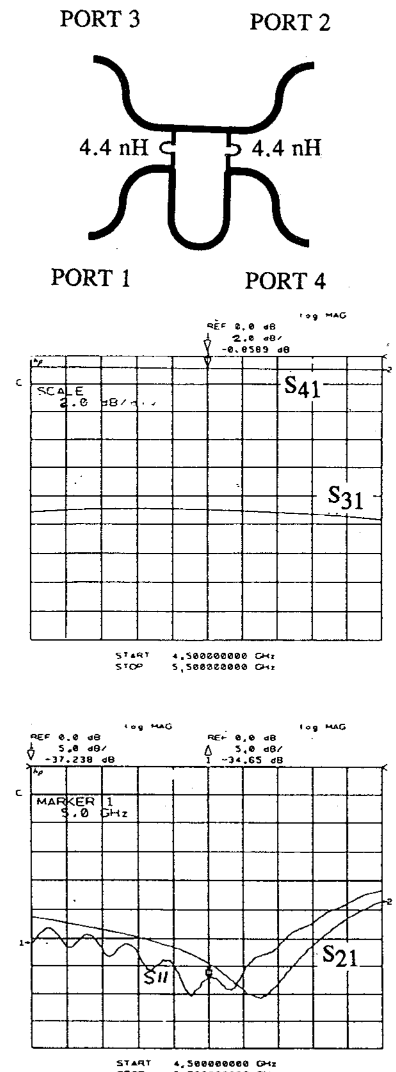


Figure 8. Physical realisation and measured performance of the rat race hybrid with 10 dB output power split ratio.