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A Compact Ultra-Wideband Double Balun Feeding Network on a Single Layer PCB

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I. Introduction

Broadband, logarithmically periodic multi-arm antennas based on the concept of self complementarity show a promising performance in **ultra-wideband** (UWB) applications and are also successfully employed in Multiple-Input-Multiple-Output (MIMO) systems. To **excite dual-linear polarisation states** in **four-arm antennas** of this kind, broadband baluns are required. In this work, a circuit consisting of **two UWB planar baluns** is presented, featuring particularly:

- Frequency range from **3.2 GHz to 9.8 GHz**
- **Single layer**, Rogers RO4003 printed circuit board, sized 50.8 mm x 50.8 mm
- Return loss at the unbalanced ports (ports 1 and 4) better than **10 dB** at 50 Ω
- Phase difference between the balanced ports between **165° and 205°**

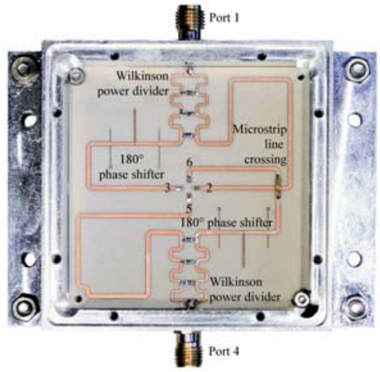

Fig. 1: Photograph of the prototype

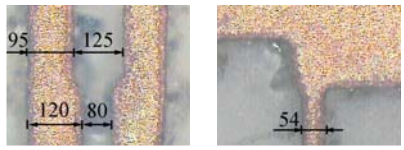

Fig. 2: Details of the 180° phase shifter (dimensions in μm)

II. Design theory

The basic circuit topology is shown in Fig. 1. Each of the two baluns consists of a **Wilkinson power divider** and a **180° phase shifter**. Furthermore, geometrical restrictions of the antenna require a **microstrip line crossing**. Each of these three subcomponents limits the S_{11} bandwidth.

To obtain a design criterion for the individual return loss of each component, an **estimation of the maximum total reflection coefficient** is made by analytically evaluating the scattering matrix of a combination of *n* symmetrical, passive, loss-less two-port networks with an individual reflection coefficient of $|S^i_{11}|$, as shown in Fig. 3. The worst-case total reflection coefficient $|S_{11}(n)|_{max}$ is then evaluated to

$$|S_{11}(n)|_{\max} = \frac{(1+|S^{i}_{11}|)^n - (1-|S^{i}_{11}|)^n}{(1+|S^{i}_{11}|)^n + (1-|S^{i}_{11}|)^n}$$

Thus, in order to achieve a **total** $|S_{11}|$ **< -10 dB** for the presented balun consisting of *n*=3 individual subcomponents, each subcomponent needs to be designed to have a reflection coefficient of less than **-19.27 dB**, as can be seen from Fig. 4.

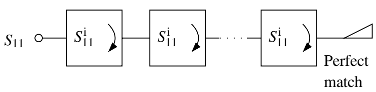

Fig. 3: Series combination of *n* symmetrical, pasive, loss-less two-port networks

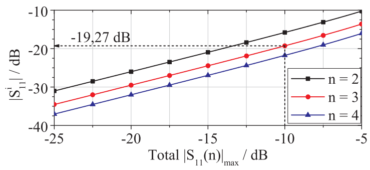

Fig. 4: Individual reflection coefficient required to guarantee a certain total reflection coefficient

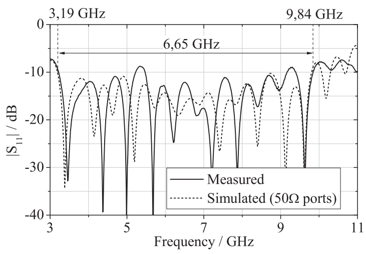

Fig. 5: Reflection $|S_{11}|$ (incl. mismatch)

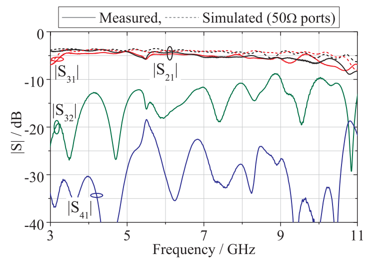

Fig. 6: Transmission and cross coupling (incl. mismatch)

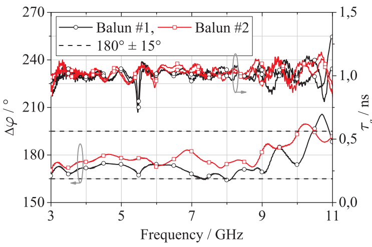

Fig. 7: Phase Δφ and group delay τ_g

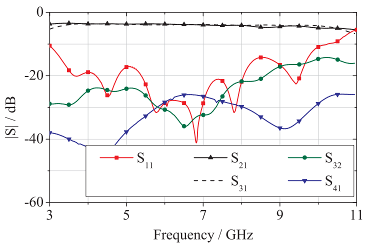

Fig. 8: Expected performance without mismatch

III. Subcomponents

Power divider

- Three stage Wilkinson power divider with U-shaped lines
- Impedance transform from 50 Ω to 75 Ω
- Return loss surpasses 18 dB between 3.0 GHz and 9.5 GHz

180° phase shifter

- Consists of coupled lines and stub lines
- Minimum line width 54 μm (see Fig. 2)
- Return loss surpasses 18 dB between 3.3 GHz and 10.9 GHz

Microstrip line crossing

- Unavoidable to excite a center-fed antenna
- Optimized bridge made of copper to decrease coupling
- Increased performance compared to a commercial zero ohm SMT resistor

IV. Simulation and measurement results

Photographs of the prototype board fabricated in a laser-based prototype process are shown in Figs. 1 and 2. For the measurement with a commercial vector network analyzer, 50 Ω coaxial connectors have to be attached to these lines causing a mismatch and thus a significant deviation from the simulation results which are consequently based on 75 Ω output ports being close to the mean input impedance of the target antenna. This mismatch is thus included in the simulation.

Key measurement results as shown in Figs. 5 – 7:

- $|S_{21}|$ **> -6.7 dB**, $|S_{31}|$ **> -6.5 dB** in the operating frequency band
- Reflection coefficient $|S_{11}|$ **< -10 dB** between 3.19 GHz and 9.84 GHz (relative bandwidth 102 %)
- **Phase shift** and **group delay** showing almost **frequency independent** behaviour, $|S_{32}|$ **< -15 dB** up to 10 GHz

As simulation and measurement show a good match, it is proven that the baluns show the expected behavior and therefore the simulation results without mismatch in Fig. 8 can be regarded as valid as well.

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