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Mohsin, I., Karlsson, M., Gong, S., (2014), Frequency diplexer network for wireless parallel data transmission and ultrawideband systems utilizing manifold technique, *Microwave and optical technology letters (Print)*, 56(8), 1869-1871. <https://doi.org/10.1002/mop.28464>

Original publication available at:

<https://doi.org/10.1002/mop.28464>

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Frequency Diplexer Network for Wireless Parallel Data Transmission and Ultra-wideband Systems Utilizing Manifold Technique

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Abstract— A frequency diplexer network for ultra-wideband radios focused on wireless parallel data transmission is presented. It has a combination of two band pass filters utilizing manifold multiplexing technique. In the frequency band 6-9 GHz, two flat sub-bands at center frequencies 6.7 and 8.3 GHz have been achieved with respect to forward transmission, input reflection and group delay. A maximum group delay variation of 0.6 ns was measured in the sub-bands. For low cost and simple circuit implementation, the design is implemented using the microstrip technology.

Key words— *diplexer; frequency division multiplexing; manifold multiplexing; ultra wideband; microstrip technology*

I. INTRODUCTION

According to the criterion of the Nyquist and Shannon theorems, data rate in wireless transmissions can be increased by increasing the bandwidth, order of modulation and signal to noise ratio [1]-[5]. Limited available frequency spectrum, channel impairment and difficulties in designing hardware for high speed or problem in dealing high frequency electronics are the reason for limited data rate in wireless networks [2]. To increase the data rate in wireless transmission, digital modulation and multiple access techniques are attractive solutions [6]-[9]. In wireless parallel data transmissions, order of modulation has an important role in the enhancement of the data rate but it also increases the complexity of the system.

As a multiple access technique, frequency division multiplexing (FDM) is a good choice for wireless parallel data transmission. FDM is a technique to transmit multiple data signal over a single transmission medium by dividing a frequency band into non-overlapping frequency sub-bands. It can be implemented utilizing Multiple Input and Multiple Output (MIMO) [10]-[11] or parallel wireless data transmission [1]-[3], [12]-[15] techniques. In MIMO, complex architectures of multiple antennas are used at both the transmitter and receivers side to increase the throughput. However, only a single antenna is needed when increasing the data rate using the wireless parallel data transmission technique.

This paper presents the simulated and measured results of a frequency diplexer network (FDN) intended for use in ultra-wideband (UWB) transmitters and receivers, while utilizing the above mentioned solution, i.e., for wireless parallel data

transmission. One of the additional challenges dealt with in this paper is the minimization of the frequency diplexer.

II. OVERVIEW OF THE SYSTEM

Figure 1 depicts the architecture of the FDM technique utilizing a receiver and transmitter for wireless parallel data transmission. It includes parallel up/down-converter, multiplexer/demultiplexer, power amplifier (PA), low noise amplifier (LNA), band pass filter (BPF) and antennas. Parallel up/down converter using a six-port correlator [2] and multiplexer/demultiplexer (Frequency multiplexing network) are important passive circuits in this architecture. The six-port correlator was already presented in previous paper [16]. Frequency multiplexing network is a reciprocal circuit, i.e., it can be operated in both ways as multiplexer or demultiplexer like any passive network [3].

Fig. 1. Wireless parallel data transmission in wireless network.

The FDM technique, which is the basic technique applied here, essentially divides the available bandwidth into two or more series of non-overlapping frequency sub-bands ($f_1, f_2, \dots, f_n$) that are assigned to each communicating source and user pair [17]. It shows two antennas for transmitter and receiver separately, but in an integrated transceiver, the receiver and transmitter can use the same antenna. In the transmitter, data stream is divided into parallel data streams and up-converted using different carrier frequencies. These up-converted signals will be transmitted by the antenna after passing through the PA. On the receiver side, selected signal from BPF will be amplified by LNA and demultiplexed into sub-bands. It is then down converted using different low frequencies and finally the signal will be fed to the baseband digital signal processing chip [2].

III. FREQUENCY DIPLEXER NETWORK

Figure 2 shows the architecture of the FDN utilizing manifold multiplexing configuration. To achieve a miniaturization of the circuit, manifold multiplexer has been chosen because it has compact but complex design [18]-[19]. It requires one filter for every sub-band frequency and gives the lowest insertion losses, optimum amplitude and group delay [3], [18]-[20]. Proposed diplexer circuit divides the 3 GHz frequency band from 6 to 9 GHz into two 1.4 GHz frequency bands. Sub-band A (6 to 7.4 GHz) is the first frequency band and sub-band B (7.6 to 9 GHz) is the second frequency band with the guard band of 200 MHz between these two bands.

It consists of two band pass filters BPF_1 and BPF_2 , two horizontal transmission lines (H_1 , H_2) for tuning filters and two series quarter-wavelength vertical transmission lines (V_1 , V_2). In FDN, series transmission lines provide high impedance to adjacent frequency sub-band. Transmission line V_1 provides high impedance to the sub-band A closing down in the manifold branch at the sub-band junction and transmission line V_2 provides high input impedance to the sub-band B. On the other hand, the horizontal transmission line is tuned to provide high impedance to the other sub-bands. The transmission line H_1 optimizes high impedance for sub-band B at BPF_1 and H_2 optimizes for sub-band A at BPF_2 .

Fig. 2. Frequency diplexer network for 6 to 9 GHz.

IV. DESIGN AND IMPLEMENTATION

Advanced Design System (ADS) software from Agilent technologies is used to design the FDN and implemented utilizing microstrip technique on the double-sided Rogers 4350B printed circuit board (PCB).

TABLE I
SUBSTRATE PARAMETERS

Dielectric thickness	254 μm
Relative dielectric constant	3.48
Dissipation factor	0.004
Metal thickness	25 μm
Metal conductivity	58 MS/m
Surface roughness	1 μm

Measurements were carried out by using Rhode & Schwartz ZVM vector network analyzer. Substrate properties are shown in Table 1.

Manifold multiplexer has three common configurations that differs how the channel filters are connected. Herringbone manifold configuration is adopted here which has filters on both side of the manifold [18].

Circuit consist of three portions namely BPF_1 , BPF_2 and a matching network. BPF_1 is designed for sub-band A by using the open circuited double stub matching network. BPF_2 is designed for sub-band B with open circuited three stubs matching network. It provides a comparatively high frequency response than BPF_1 . It is realized using two narrow stubs and having the height of 17 mm.

Fig. 3. Layout of frequency diplexer network for 6 to 9 GHz.

Fig. 4. Manufactured frequency diplexer network for 6 to 9 GHz.

After designing BPF_1 and BPF_2 , both the filters are connected with common port P1 by using a matching network which consists of four transmission line as shown in figure 3. Port P2 is for the sub-band A and port P3 for the sub-band B. The size of this diplexer is 17 mm x 41 mm which is quite compact considering the technology of implementation. Figure 4 shows a photo of the diplexer PCB prototype. Three subminiature A (SMA) connectors are soldered for measuring the results.

V. SIMULATED AND MEASURED RESULTS

Simulated and measured results of the forward voltage transmission for the purposed diplexer are present in the Figure 5(a). It has a reasonably flat response for band pass in each targeted band of the 1.4 GHz within -3 dB from the top. It is found that the matching network between the filters is tuned enough to stop the neighbouring sub-band. It also shows

good agreement between the simulated and the measured results.

Same as forward voltage transmission, input reflection response for the simulated and measured results is fairly flat that can be observed in the figure 5 (b). Simulated insertion loss for both bands is between 0.6 to 2.1 dB and the measured insertion loss is 3.0 to 4.9 dB. The minimum isolation between the ports (P2 and P3) is 12 dB, which is at the boundary between the two sub-bands and for the both bands the isolation is greater than 12 dB.

Figure 5 (c) shows simulated and measured results for the group delay. For each sub-band, the maximum group delay is around 1 ns and the maximum variation in the delay is about 0.6 ns.

Fig. 5. FDN results for Sub-band A and B, (a) simulated and measured forward transmission, (b) simulated and measured input reflection, and (c) simulated and measured group delay.

VI. DISCUSSION

In general a good match was observed between simulated and measured results. However, some discrepancies also exist. Firstly, SMA connectors are not included in the simulations and secondly, ADS 2009 Momentum (ADS electromagnetic simulator) does not take surface roughness into account [13]. Comparing the results, there is a difference of 2.8 dB between the measured and simulated results for the insertion loss. The main reason for this difference is the fact that surface roughness tends to increase the insertion loss [21]-[22], and ADS 2009 as mentioned earlier, does not account for surface roughness in its simulations. The size of this diplexer is 17 x 41 mm which ought to be small enough when targeting reduction in the overall size of a UWB transmitter or receiver.

I. CONCLUSION

A compact frequency diplexer network using the microstrip technology for the UWB band is demonstrated. Two flat sub-bands in the frequency band of 6-9 GHz have been achieved. Typically a guard band has 10% relative bandwidth but here sub-band A (6-7.4 GHz) and sub-band B (7.6-9 GHz) are separated by a guard band of 200 MHz, i.e. with a guard band of 2.6% relative bandwidth at 7.5 GHz. For both the bands 0.6 to 2.1 dB insertion loss has been achieved, and also has 1 ns maximum group delay with a variation of 0.6 ns. The diplexer is implemented on printed circuit board with a size of 17 x 41 mm.

ACKNOWLEDGEMENT

The authors would like to show deep respect and want to say special thanks to Mr. Gustav Knutsson at the Department of Science and Technology for his assistance in the printed circuit board manufacturing process.

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