Compact Highly Selective DCS1800 Duplexer for Mobile Base Station

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Abstract—this paper presents a compact microstrip duplexer used for cellular base station. The duplexer is composed of two fifth order bandpass filters with sharp edges and a T-junction. One of bandpass filters is utilized to operate in DCS-Rx band and the other operates in DCS-Tx band. Each bandpass filter is composed of a combination of two tapped-line geometry, two coupled lines structure and two $\lambda_g/2$ resonators. The designed DCS-Rx BPF and the DCS-Tx BPF present a size reduction of 36.58 % and 59.15 %, respectively than the conventional parallel coupled microstrip line with the same order (N=5). The duplexer is designed and fabricated on Roger RT/Duroid 5880 with relative dielectric constant of 2.2, and substrate height of 0.7874 mm. The average measured insertion losses at the DCS-Rx and DCS-Tx bands are 1.95 dB and 2.02 dB, respectively. The minimum measured isolation between the transmitting and the receiving bands of DCS1800 is 24.88 dB. Also, the return losses for the input and the outputs indicate that the duplexer operates at the assigned Rx and Tx bands of DCS1800.

Index Terms— Cellular base station, duplexer, DCS1800 band, isolation, sharp roll-off, bandpass filter, microstrip.

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1 INTRODUCTION

Since the number of wireless applications increases and with the additional need for more mobile service with high-quality in mobile communication systems, the upgrading to new generations of mobile technology is becoming the best choice for mobile operators to overcome the customers' needs. Instead of designing different antennas for the different applications and designing different antennas for each transmitter and receiver, the mobile operators install frequency combiners, where it includes duplexer. The duplexer enables operators to use feeder sharing especially when the distance between the base station and the antenna is long or when building or - tower restrictions keep operators from installing more feeders at a site. The duplexer is a passive device placed between the transmitting and receiving circuits which used to route the transmitting signal from the transmitter to the antenna and with a reciprocal function routes the received signal from the antenna to the receiver simultaneously while producing isolation between the transmitter and the receiver. The duplexer consists of two different band pass filters and a combination structure such as T-junction in order to share one common antenna simultaneously. One of the two band pass filters placed at the transmitting side is used to permit the transmitter to operate at a desired frequency band while the other placed at the receiving side is used to permit the receiver to operate at a different frequency band.

The duplexer mainly used when the transmitted and the received signals are closed together, so the two band-pass filters must have a sharpness edge at the guard band between them to separate these frequencies. When designing a duplexer, a high level of isolation is required to ensure that the minimum level of the transmitter power reaches the receiver to protect it from damage. When the two operating bands are too closed together, one of the solutions for designing the duplexer is to implement two filters associated with matching networks [1]. The duplexer is composed of a single dual band bandpass filter and two associated matching circuits [1]. Although, there is only one bandpass filter used in the duplexer but it is difficult to implement closed dual bandpass filters. Also, the size of the matching circuits may be increased due to including open stubs in each branch of the duplexer. A constant impedance / balanced duplexer used for receiving and transmitting bands of DCS1800, is reported in [2]. The duplexer consists of two band-stop filters, two 3-dB hybrid couplers and a dummy load. Both filters are designed to act as stop-band at frequency from 1.71 GHz to 1.785 GHz and passband from 1.805 GHz to 1.88 GHz. But this duplexer is complicated and requires more components, so, an extra cost will be added. Also, at high power, the matched load has great weight that could be up to several kilograms. The duplexer is based on filters with eight poles of square open loop resonators, having internal stubs in [3]. The insertion of some stubs inside the square open loop resonator allows changing their resonant frequency to lower values. But the insertion loss is less than 5 dB for the two bandpass filters.

DCS1800 (Digital Cellular System) is one of important bands used in mobile communications which occupy the frequency range of (1710-1880) MHz. In DCS1800 the assigned band (1710-1785) MHz is used for receiving operation (downlink) and the band (1805-1880) MHz is used for transmitting operation (uplink). The assigned bandwidth for both uplink and downlink is equal 75 MHz and the guard band that located between transmitting and receiving band is only 20 MHz.

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Based on that, two bandpass filters with high selectivity are required in order to separate the Rx and Tx bands due to the existence of the very narrow guard band between them.

In this paper, a new solution for designing a compact microstrip duplexer in order to route two close bands that are used for mobile base station system with a good isolation between them is presented. The proposed duplexer need no matching network compared with those in literatures [1]. Each bandpass filter is composed of a combination of two tapped-line geometry at the input and the output of the filter [4] – [6], two coupled lines structure at the middle and two λg/2 resonators. The organization of the paper is as follows: Section 2 introduces the proposed DCS-Rx bandpass filter design with λg/2 parallel stub. Section 3 presents the proposed DCS-Tx bandpass filter design with λg/2 parallel stub. The final design of a DCS1800 duplexer with fabricated photos is presented in section 4. Conclusion is given in section 5.

2 PROPOSED DCS-RX BANDPASS FILTER DESIGN WITH HALF WAVELENGTH PARALLEL STUB

The proposed solution to solve a weak isolation between DCS-Rx and DCS-Tx problem is to increase the order of the filter or to add a λg/2 parallel stub as shown in Fig. 1. A λg/2 parallel stub is added before the coupled line at the front and the end of the coupled line. The λg/2 parallel stub acts as a uniform impedance resonator (UIR). The optimized dimensions value of the proposed DCS-Rx bandpass filter with uniform impedance resonator (UIR) is shown in Table 1.

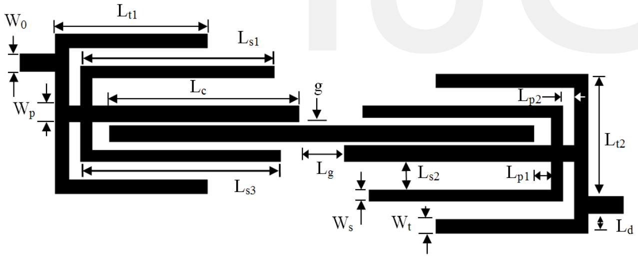


Fig.1. Proposed DCS-Rx bandpass filter with a combination of tapped-line geometry and coupled line structure

TABLE 1
THE OPTIMIZED DIMENSIONS OF THE PROPOSED FIFTH ORDER DCS-RX BANDPASS FILTER

Parameter	Value (mm)	Parameter	Value (mm)
W_0	2.42	L_g	6.4
L_{t1}	21.44	L_d	2.75
W_t	1.92	g	0.45
W_p	2.22	L_{s1}	27.3
L_{t2}	16.94	L_{s2}	3.9
L_c	26.75	L_{s3}	28.2
L_{p1}	2.45	W_s	1.6
L_{p2}	1.65		

Tapped lines geometry can be used in order to overcome the limitation of realization of tight coupling mechanism by placing the tapped line at the front and the end (exterior coupled line sections) of the filter instead of the narrow coupled line [6]. The input and output asymmetric feed line tapping the resonators divide the resonators into two sections of l_1 and l_2. The total length of the resonator is λg/2, where λg is the guided wavelength at fundamental resonance as shown in Fig. 2. Fig. 3 shows the simulated transmission coefficient and the reflection coefficient of the proposed DCS-Rx band pass filter with λg/2 uniform impedance resonator compared to the conventional parallel couple microstrip line (PCML) with fifth order. It is shown from Figure 3 that there are three poles over the passband region and two transmission zeros at the upper side stopband region of the passband.

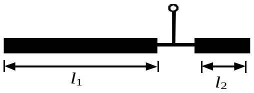


Fig. 2 The configuration of the λg/2 resonator with asymmetric tapping feed lines.

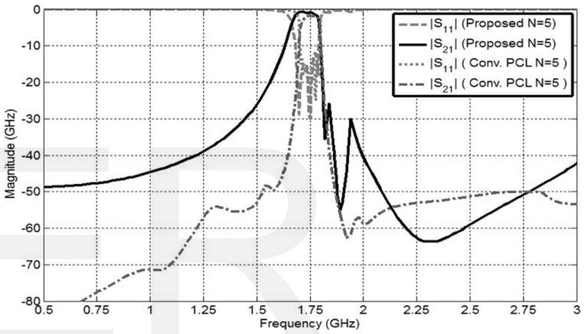


Fig. 3 The simulated transmission coefficient (|S21|) and reflection coefficient of the proposed fifth order DCS-Rx band pass filter with λg/2 uniform impedance resonator compared with conventional parallel coupled line filter.

The first transmission zeros occurs at f = 1.82 GHz with attenuation value of -35.42 dB and the second transmission zeros occurs at f = 1.89 GHz with attenuation value of -54.8 dB which improve the stop band characteristic within the DCS-Tx operating band (1.805-1.88) GHz. Also, the minimum attenuation value of the stop band at the start of the DCS-Tx band is -20.36 dB which represents a good isolation between DCS-Rx and DCS-Tx bands. It is noticed from Fig. 3 that, the obtained sharpness at the right edge of the pass band looks like that in the conventional parallel couple line band pass filter with order of N=5. The sharp roll-off of the proposed fifth order bandpass filter is 950.78 dB/GHz.The filter has a pass bandwidth of 121.3 MHz (1.6697 - 1.791) GHz with good matching without unrealizable gaps between the middle coupled lines. The size of the filter is 85.14 x 67.23 mm^2 which represents 36.58 % reduction of size than the conventional coupled line with the same order (N=5).

3 PROPOSED DCS-TX BANDPASS FILTER DESIGN WITH HALF WAVELENGTH PARALLEL STUB

Similarly, for the transmitting side, the proposed fifth order DCS-Tx bandpass filter with uniform impedance resonator ($\lambda g/2$ parallel stub) is utilized to solve a weak isolation between DCS-Rx and DCS-Tx problem as shown in Fig. 4. A $\lambda g/2$ parallel stub is added before the coupled line at the front and the end of the coupled line. The $\lambda g/2$ parallel stub acts as a uniform impedance resonator (UIR). The optimized dimensions of the proposed DCS-Tx bandpass filter with uniform impedance resonator (UIR) are shown in Table 2. Fig. 5 shows the simulated transmission coefficient ($|S_{21}|$) and reflection coefficient ($|S_{11}|$) of the proposed band pass filter with $\lambda g/2$ uniform impedance resonator compared to the conventional parallel coupled line filter with fifth order.

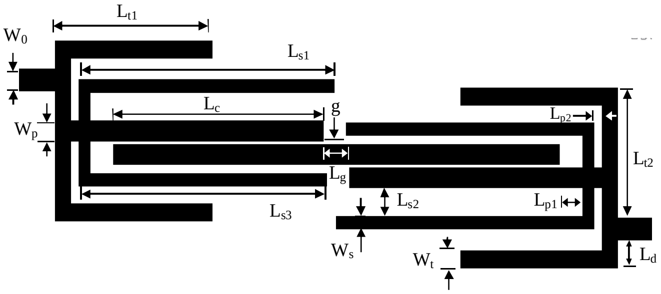


Fig. 4 Proposed DCS-Tx bandpass filter with a combination of tapped-line geometry and coupled line structure

	(mm)		(mm)
W_0	2.42	L_g	3.8
L_{t1}	19.17	L_d	3.05
W_t	1.92	g	0.45
W_p	2.22	L_{s1}	31.2
L_{t2}	14.24	L_{s2}	3.1
L_c	25.35	L_{s3}	30.25
L_{p1}	2.8	W_s	1.4
L_{p2}	0.95		

It is shown from Fig. 5 that, there are two poles over the passband region and three transmission zeros. Two transmission zeros located at the lower side stopband region from the passband and one located at the upper stopband region from the passband. The reason behind designing a transmission zero at the upper stopband region from the passband is that the UMTS2100 band is located beside the DCS1800-Tx. The first and the second transmission zeros occur at f = 1.618 GHz and f = 1.775 GHz with attenuation values of -35.61 dB and -34.19 dB, respectively which improve the stop band characteristic within the DCS-Rx operating band (1.71-1.785) GHz. The third transmission zero located at 2.02 GHz with attenuation value of - 49.19 dB occurs at the right side of the passband region. The minimum attenuation value of the stop band at the end of the DCS-Rx band is -34.29 dB which represents a good isolation between DCS-Rx and DCS-Tx bands.

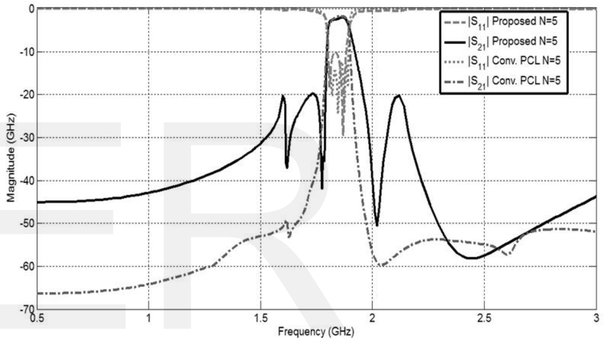


Fig. 5 Proposed DCS-Tx bandpass filter with a combination of tapped-line geometry and coupled line structure.

Also, it is noticed from Fig. 5 that the obtained sharpness at the right edge of the pass band looks like that in the conventional parallel couple line band pass filter with order N=5. The sharp roll-off of the proposed third order bandpass filter is 1302.68 dB/GHz. The filter has a pass bandwidth of 92 MHz (1.804- 1.896) GHz with a good matching. Furthermore, there are no unrealizable gaps between the middle coupled lines. The size of the filter is 77.44 x 45.83 mm^2 which represent 59.15 % reduction of size than the conventional parallel coupled line filter with the same order (N=5).

4 A DCS1800 DUPLEXER DESIGN

A duplexer in mobile base station system is used in order to limit extra feeder. Based on that, a DCS1800 duplexer is proposed to separate/combine between the DCS-Rx and DCS-Tx bands. Fig. 6 shows the circuit layout diagram of the proposed DCS1800 duplexer. The duplexer consists of two fifth order bandpass filters connected together by a T-junction. The two bandpass filters are one utilized for DCS-Rx band and the other is utilized for DCS-Tx band. The proposed duplexer has three ports; the first port is a common port, the second port is

Rx port, and the third port is Tx port. Port 1 represents a common port which the transmitted and the received signals pass through it in an opposite direction with an isolation between them.The T-junction is optimized in order to serve the isolation between DCS-Rx and DCS-Tx bands.

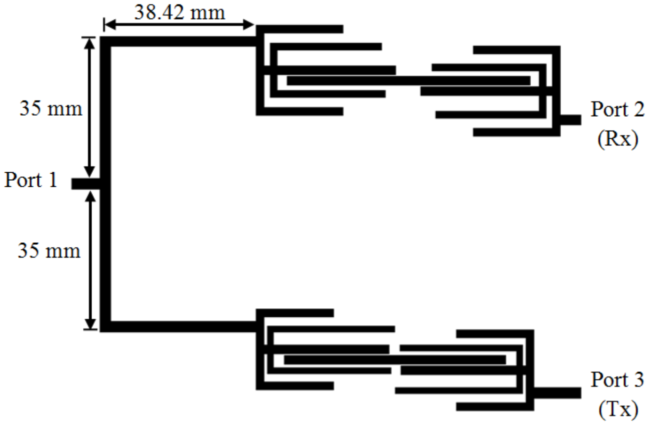


Fig. 6 The circuit layout diagram of the proposed DCS1800 duplexer

The overall size of the proposed DCS1800 duplexer is 125.56 x 134.23 mm^2. The numerical results of the DCS1800 duplexer is simulated by using a full-wave EM simulator IE3D Zeland ver. 12. The duplexer is fabricated on a Roger RT / Duroid substrate with relative dielectric constant (ε_r) of 2.2, substrate height (h) of 0.7874 mm (31-mil) and loss tangent (tan δ) of 0.0009. The experimental results are measured by Agilent HP8719ES vector network analyzer. Fig. 7 shows the simulated and the measured transmission coefficients ($|S_{21}|$ and $|S_{31}|$) for both DCS-Rx and DCS-Tx bands / ports.

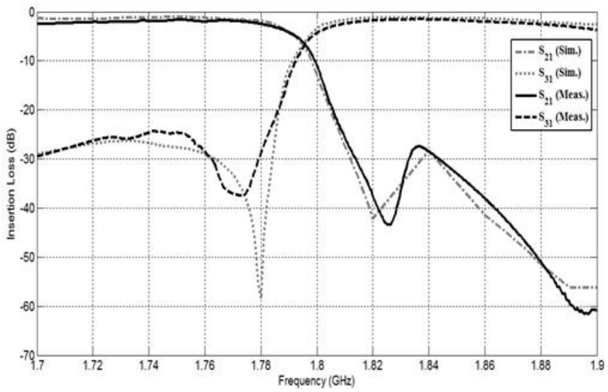


Fig. 7 The simulated and measured transmission coefficients ($|S_{21}|$ and $|S_{31}|$) for both DCS-Rx and DCS-Tx ports.

The average simulated and measured values of the insertion losses at the Rx-band are 1.65 dB and 1.95 dB, respectively. While, the average simulated and measured values of the insertion losses at Tx-band are 1.59 dB and 2.02 dB, respectively. Fig. 8 shows the simulated and the measured isolation between the output ports ($|S_{23}|$) and input reflection coefficient ($|S_{11}|$). It depicts from Fig. 8 that the minimum simulated and measured isolation at Rx-band (Rx-port) are 28.03 dB and 25.49 dB, respectively. The minimum simulated and measured isolation at Tx-band (Tx-port) are 29.38 dB and 24.88 dB, respectively.

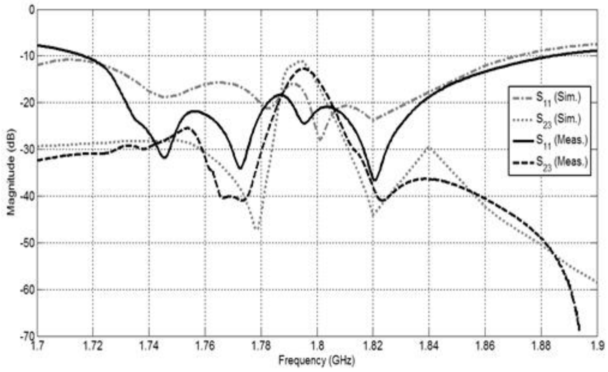


Fig. 8 The simulated and measured isolation between the output ports ($|S_{23}|$) and input reflection coefficient ($|S_{11}|$).

It is noticed from Fig. 8 that the input reflection ($|S_{11}|$) indicates that the duplexer operates at the assigned receiving and transmitting bands of DCS1800. Fig. 9 shows the simulated and measured reflection coefficients for the two output ports ($|S_{22}|$) and ($|S_{33}|$). It is shown in Figure that the return loss at port 2 covers the assigned DCS-Rx band (1.71-1.785) GHz and the return loss at port 3 covers the assigned DCS-Tx band (1.805-1.88) GHz. Fig. 10 shows the photograph of the fabricated DCS1800 duplexer.

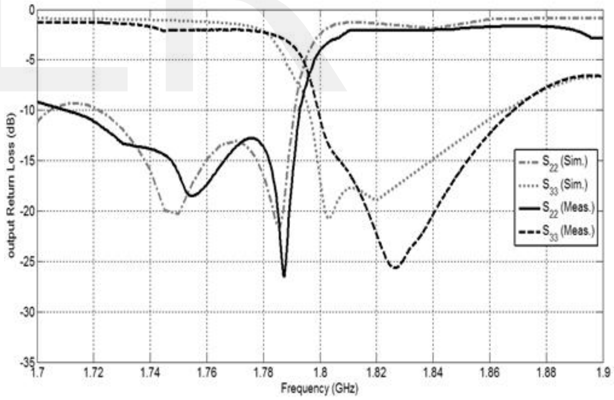
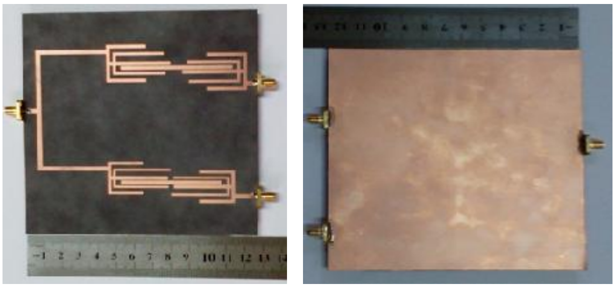


Fig. 9 The simulated and measured reflection coefficients for the two output ports ($|S_{22}|$) and ($|S_{33}|$).



(a) (b)

Fig. 10 The photograph of the fabricated DCS1800 duplexer: (a) Top view (b) Bottom view

5 CONCLUSIONS

A compact microstrip duplexer used for mobile base station system is designed in order to reduce the number of feed lines between the mobile base station indoor racks and the tower mounted unit. The duplexer consists of two bandpass filters with fifth order and a T-junction. One of the bandpass filters is utilized to cover the DCS-Rx band and the other covers the DCS-Tx band. Each bandpass filter composed of a combination of two tapped-line geometry at the input and the output of the filter, two coupled lines structure at the middel and two $\lambda g/2$ resonators. The size of the DCS-Rx and the DCS-Tx bandpass filters are 85.14 X 67.23 mm^2 and 77.44 X 45.83 mm^2 which represent 36.58 % and 59.15 %, respectively reduction of size than the conventional coupled line filter with the same order (N=5). The design has been performed and simulated with the aid of a full-wave EM simulator IE3D Zeland ver. 12. The duplexer is fabricated on Roger RT/Duroid 5880 with relative dielectric constant of 2.2 and substrate height of 0.7874 mm. The average measured insertion losses at the DCS-Rx and DCS-Tx bands are 1.95 dB and 2.02 dB, respectively. The minimum measured isolation between the transmitting and receiving bands of DCS1800 were 25.49 dB dB and 24.88 dB, respectively. Also, the return losses for the input and the outputs indicate that the duplexer operates at the assigned Rx and Tx bands of DCS1800. The sharp roll-off for the proposed transmitting and receiving bandpass filters are 950.78 dB/GHz, 1302.68 dB/GHz, respectively. The overall size of the proposed DCS1800 duplexer is 125.56 x 134.23 mm^2.

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