An Asymmetric Dual-band HTS Band-pass Filter for American Mobile Phone System

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Abstract— The American Mobile Phone System (AMPS) has a very complex frequency allocation which is divided between two operators A and B. Therefore, high performance multiple-band system components are desired in both the downlink and uplink. High Temperature Superconducting (HTS) filter and amplifier can be used in the reverse link reception where high sensitivity is desired and the power is within the range that HTS can handle. In this paper, we introduce a nine-pole bandpass filter to be used in operator B for reverse link reception. The filter is an example of dual-band filter with asymmetric response.

1. INTRODUCTION

Modern mobile communication systems require improved sensitivity and selectivity to support the growth in multimedia services, increased coverage, longer talk time and large number of subscribers. This in turn leads to demands for highly selective RF filters. This also forces the operators to seek more efficient sharing of the limited frequency spectrum. This initiates the need for HTS single and multiple bandpass filters to be used in the base stations in order to efficiently utilize the limited space [1–3].

The American Mobile Phone System (AMPS) uses the frequency band from 824 to 849 MHz for communication from the handset to their base stations (the uplink) and 896.0 to 894.0 MHz for the communication from the base stations to the handset (the downlink). This enables full duplex conversation. Historically, a band A and a band B were allocated first, then further allocations of A' and B' were given by the Federal Communications Commission (FCC) to mobile radio. The allocated spectrum gives 416 channels with a bandwidth of 30 kHz for each of the operator [4].

Figure 1 shows these allocations in more detail. In every region, two providers (denoted A and B) share this spectrum in non-contiguous segments. This complex allocation leads to potential operational problems. Cross-talk at the band edges between the two operators can lead to interference problems, with the consequence of unusable channels [4]. Limiting interference with the non-contiguous frequency allocations often requires highly selective filters that can easily be realized using HTS technology.

This gives rise to the need for four distinguishable filters for the whole system. Each one is a dual-band with (A, A') or (B, B') bandwidths for both uplink and downlink. It is worth noting that the only difference between the uplink filter and the downlink filter is in the centre frequency, as the bandwidth of each band does not change.

Each filter must have a very rapid roll off (within each 30 kHz channel) and provide high adjacent channel attenuation at the operators' band edges. This has been previously attained by cavity filters where a surrounding cylinder is coated with thick film HTS material and has an internal HTS thick-film split ring resonator [4]. For example, 16 and 10 pole filters have been used for the lower and upper bands respectively for operator A. The filters have been also designed using HTS thin-film but again two distinctive filters have been used to achieve the dual-band performance [5].

In this paper, a nine-pole planar bandpass HTS filter is presented. The filter can be used on the used for reception on the masthead for B operator. A symmetrical triple band HTS filter has been previously designed using an optimization algorithm introduced in [3]. The same algorithm has been used to design the desired asymmetric dual-band filter.

2. FILTER SPECIFICATIONS

A filter is designed for the base station receiver for band B and B'.

Centre frequency = 842 MHz, **Stop-band bandwidth** = 1.5 MHz,
1st passband bandwidth = 10 MHz, and **2nd passband bandwidth** = 2.5 MHz.

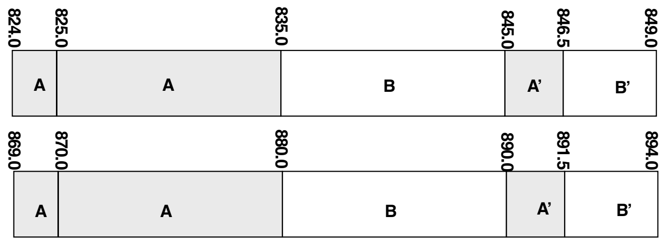

Figure 1: Channel allocations for mobile radio in the USA for base station and mobile handsets. Frequencies are given in MHz [4]; The top is the mobile transmission spectrum allocation and the bottom is the base transmission spectrum allocation.

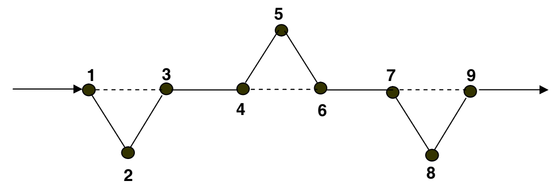

Figure 2: Trisection cascaded topology for the nine-pole dual-band asymmetric HTS filter for mobile communication.

Table 1: Coupling Matrix for the 9th Order Asymmetrical Dual Pass-band Filter.

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	−.0732	.0863	0.7575	0	0	0	0	0	0
2	.0863	.5504	0.2239	0	0	0	0	0	0
3	.7575	.2239	−.0477	.4977	0	0	0	0	0
4			.4977	−.087	.1714	.4986	0	0	0
5				.1714	.5841	.1722	0	0	0
6				.4986	0.1722	−.0868	0.4977	0	0
7						.4977	−.0482	.2236	.7574
8							.2236	0.5509	.087
9							.7574	.087	−.0732

3. FUNCTION OPTIMIZATION

To achieve the specified response, a nine-resonator trisection filter has been chosen. The topology filter is depicted in Fig. 2, where the solid line indicates the direct couplings and the dashed lines indicate cross couplings. The filter consists of three-cascaded trisections, each of these has one cross coupling that enable the production of a single attenuation pole at finite frequency. This topology has been chosen as it allows an asymmetrical response. The other advantage of this topology is that it minimizes the spurious coupling by allowing a good separation between non-adjacent and non-coupled resonators compared to cascaded quadruplets or canonical topologies.

Another merit is that each transmission zero is controlled by one cross coupling from the related tri-section which enables relatively easy tuning on both simulation and manufacturing levels. However, the total number of transmission zeros to be realised is less compared to the canonical topology.

To realize these specifications, the full coupling matrix is constructed using the synthesis method developed by Cameron [6]. The coupling matrix has been synthesized to the desired topology using optimization method developed by Jayyousi [7]. Table 1 gives the resultant matrix and the response is depicted in Fig. 3.

4. FILTER FABRICATION

The filter layout is shown in Fig. 4 where the main resonator is the highly miniaturized interdigital dual-spiral resonators developed by Zhou [8]. The resonators have a very low sensitivity to the substrate thickness variation and a small far-field radiation which makes them suitable for a small fractional bandwidth. The resonator dimensions have been found to be 4.25 mm × 1.95 mm and the resonator line-width is 50 μm.

The filter design was carried out according to the coupled-resonators design methodology, which is covered in [9]. The substrate is MgO with a thickness of 0.5 mm and the chip size is 32 mm × 12 mm, using YBCO thin film on both sides of the substrate. The filter has been simulated and optimized using Sonnet software [10] with a resolution of 50 μm × 50 μm. The simulation results are depicted in Fig. 5.

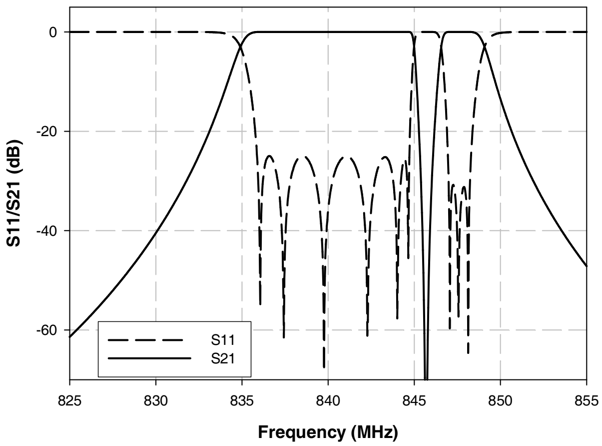

Figure 3: Reflection and insertion losses for the 9-pole asymmetrical dual-passband filter (theoretical).

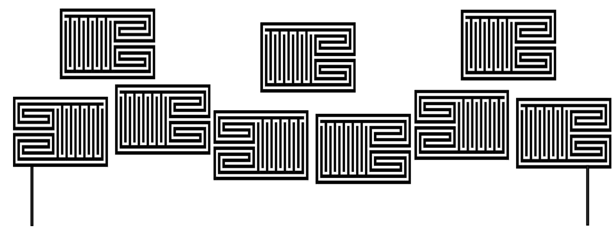

Figure 4: The nine-pole dual-band asymmetric HTS filter layout for downlink in American mobile communication (Figure is not to scale).

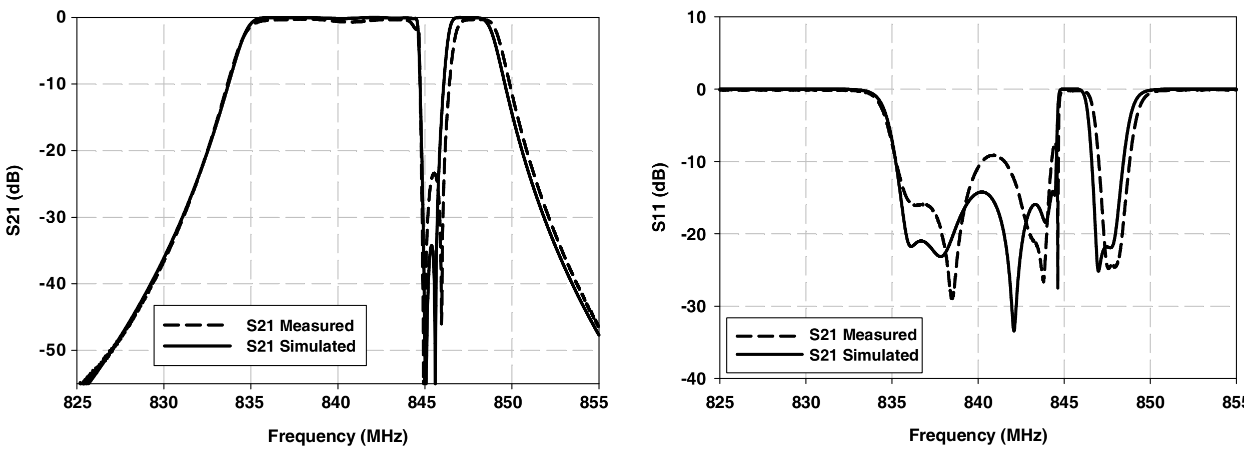

Figure 5: Measured and simulated reflection and insertion losses for the 9-pole asymmetrical dual-passband filter.

5. MEASUREMENT RESULTS

The experimental result is depicted in Fig. 5. The centre frequency is shifted down by 4.85 MHz from the simulated response.

Without any tuning, the resultant total bandwidth is 14.3672 MHz with a discrepancy of 0.3672 MHz compared to the designed one; the passbands are 9.9727 MHz, and 2.1953 MHz. The maximum rejection is −7.743 dB for the first passband and −24.05 dB for the second passband. The maximum insertion losses in the passbands are −0.23 dB and −0.279 dB.

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