Volume : 5 | Issue : 1 | January 2016 ISSN - 2250-1991

Research Paper Engineering

Ultra-Wideband Rf Modules for Communication Systems

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ABSTRACT

Communication and Radar industry in microwave and mm wave frequencies is currently in continuous growth. Radio Frequency modules such as Front End, Filters, Power Amplifiers, Antennas, Passive Components and Limiters are important modules in Radar and communication links. Accurate design of mm wave RF modules is crucial. Several ultra-wideband RF modules are presented in this paper. Development and design considerations of a compact
Wideband 18 to 40GHz Front End and Switch Filter Bank Filter are described in this paper. The RF modules and the system was designed by using ADS system software and momentum RF software.

KEYWORDS MM Wave, RF Head, RF Modules, Communication Systems

INTRODUCTION

Communication and Radar industry in microwave and mm wave frequencies is currently in continuous growth. Radio Frequency modules such as Front End, Filters, Power Amplifiers, Antennas, Passive Components and Limiters are important modules in Radar and communication links, [1-5]. The electrical performance of the modules determines if the system will meet the required specifications. Moreover, in several cases the modules performance limits the system performance. Minimization of the size and weight of the RF modules is achieved by employing MMIC and MIC technology. However, integration of MIC and MMIC components and modules raise several technical challenges. Design parameters that may be neglected at low frequencies cannot be ignored in the design of wide band integrated RF modules. Powerful RF design software, such as ADS and HFSS, are required to achieve accurate design of RF modules in mm wave frequencies. Accurate design of mm wave RF modules is crucial. It is an impossible mission to tune mm wave RF modules in the fabrication process. Development and

18 to 40 GHz Front End Requirements

The frontend electrical specifications are listed in Table 1. The frontend design presented in this section meet the frontend electrical specifications.

Parameter	Requirements	Results
Frequency range	18-40GHz	Comply
High Gain Low Gain	24 dB 3dB	Comply
Gain flatness 18-40GHz. for any 0.5GHz BW for any 4GHz BW	±3dB max ±0.5dB max ±2dB max	Comply
Noise Figure	10dB max for 40°C	Comply
Input power	-60dBm to 10dBm	Comply
Output power	-39dBm to 11dBm	Comply
Linearity 1dBC IP3	12dBm min. 21dBm	Comply
VSWR	2:1	Comply
Power Input protection	No damage at +30dBm CW	Comply
Voltages	±5V, ±15V	Comply
Control Logic	"0" = 0-0.8V; "1" = 2.0-3.3V	Comply
Switching Time	Less than 100nsec	Comply
Dimensions	60X40X20mm	Comply

The RF Head connector list is given in Table 2.

Table 1: Frontend Electrical Specifications

Table 2: Interfaces Connectors

Interface	Type
RF input	Wave guide WRD180 (Double Ridge)
RF output	K Connector
DC Supply	D Type
Control	D Type

Front End Design

Frontend block diagram is shown in Fig. 1. The frontend module consists of a limiter and a wideband 18 to 40GHz. Filtronic, low noise amplifier LMA406. The LMA406 gain is around 12Db with 4.5dB noise figure and 14dBm saturated output power. The LNA dimensions are 1.44x1.1mm. We used a wide band PHEMT MMIC SPDT manufactured by Agilent, AMMC-2008. The SPDT insertion loss is lower than 2dB. The isolation between the SPDT input port to the output ports is better than 25dB. The SPDT 1dBc compression point is around 14dBm. The SPDT dimensions are 1x0.7x0.1mm. The frontend electrical characteristics was evaluated by using ADS Agilent software and by using SYSCAL software. Figure 2 presents the frontend module noise figure and gain for LNA noise figure of 6dB. The overall computed module noise figure is 9.46dB. The module gain is 21dB. Figure 3 presents the frontend module noise figure and gain for LNA noise figure of 5.5dB. The overall computed module noise figure is 9.25dB. The module gain is 21dB. The MMIC amplifiers and the SPDT are glued to the surface of the mechanical box. The MMIC chips are assembled on a Covar carriers. During development it was found that the spacing between the frontend carriers should be less than 0.03mm in order to achieve flatness requirements and V.S.W.R better than 2:1.

The frontend voltage and current consumption are listed in Table 3. The frontend module has a high gain and low gain channels. The gain difference between high gain and low gain channels is around 15 to 20dB. Measured frontend gain is presented in Fig. 4. The frontend gain is around 20+4dB for the 18 to 40GHz frequency range.

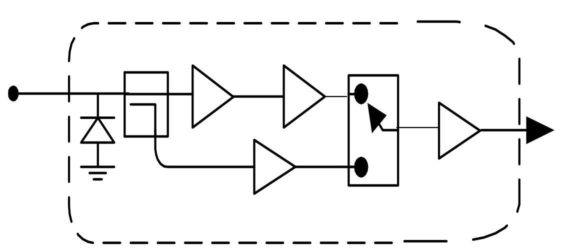
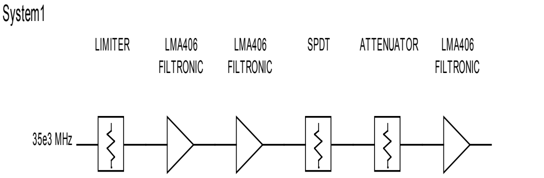


Figure 1: Frontend block diagram

ISSN - 2250-1991



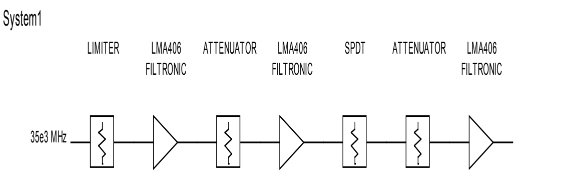
							Total
NF (dB)	3.00	6.00	6.00	3.00	3.00	6.00	9.46
Gain (dB)	-3.00	10.00	10.00	-3.00	-3.00	10.00	21.00
OIP3 (dBm)	30.00	25.00	25.00	30.00	30.00	25.00	23.14

Input Pwr (dBm)	-60.00	System Temp (K)	290.00	IM Offset (MHz)	.025
OIP2 (dBm)	23.14	OIP3 (dBm)	23.14	Output P1dB (dBm)	11.37
IIP2 (dBm)	2.14	IIP3 (dBm)	2.14	Input P1dB (dBm)	-8.63
OIM2 (dBm)	-101.14	OIM3 (dBm)	-163.28	Compressed (dB)	0.00
ORR2 (dB)	62.14	ORR3 (dB)	124.28	Gain, Actual (dB)	21.00
IRR2 (dB)	31.07	IRR3 (dB)	41.43		
SFDR2 (dB)	61.34	SFDR3 (dB)	81.79	Gain, Linear (dB)	21.00
AGC Controlled Range:		Min Input (dBm)	N/A	Max Input (dBm)	N/A

Figure 2: Frontend module design for LNA N.F=6dB

Table 3: Frontend module Voltage and current consumption

Voltage (v)	3	5	-12	-5	5 Digital
Current (A)	0.25	0.15	0.1	0.1	0.1



								Total
NF (dB)	3.00	5.50	3.00	5.50	3.00	1.00	5.50	9.25
Gain (dB)	-3.00	10.50	-3.00	10.50	-3.00	-1.00	10.00	21.00
OIP3 (dBm)	30.00	25.00	30.00	25.00	30.00	30.00	25.00	23.61

Input Pwr (dBm)	-60.00	System Temp (K)	290.00	IM Offset (MHz)	.025
OIP2 (dBm)	24.04	OIP3 (dBm)	23.61	Output P1dB (dBm)	11.74
IIP2 (dBm)	3.04	IIP3 (dBm)	2.61	Input P1dB (dBm)	-8.26
OIM2 (dBm)	-102.04	OIM3 (dBm)	-164.23	Compressed (dB)	0.00
ORR2 (dB)	63.04	ORR3 (dB)	125.23	Gain, Actual (dB)	21.00
IRR2 (dB)	31.52	IRR3 (dB)	41.74		
SFDR2 (dB)	61.90	SFDR3 (dB)	82.24	Gain, Linear (dB)	21.00
AGC Controlled Range:		Min Input (dBm)	N/A	Max Input (dBm)	N/A

Figure 3: Frontend module design for LNA N.F=5.5dB

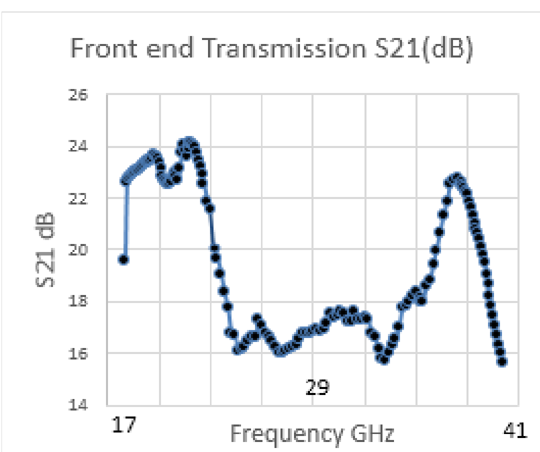


Figure 4: Measured frontend gain

High gain frontend module

To achieve a high gain frontend module a medium power Hittite MMIC amplifier, HMC283, was added to the frontend module as presented in Figure 5. The HMC283 gain is around 21dB with 10dB noise figure and 21dBm saturated output power. The amplifier dimensions are 1.72x0.9mm. The high gain frontend module block diagram is shown in Figures 5 and 6. The frontend module has a high gain and low gain channels. The gain difference between high gain and low gain channels presented in Fig. 5 is around 15 to 20dB. The gain difference between high gain and low gain channels presented in Fig. 6 is around 10 to 15dB. Detailed block diagram of high gain module is shown in Fig. 7.

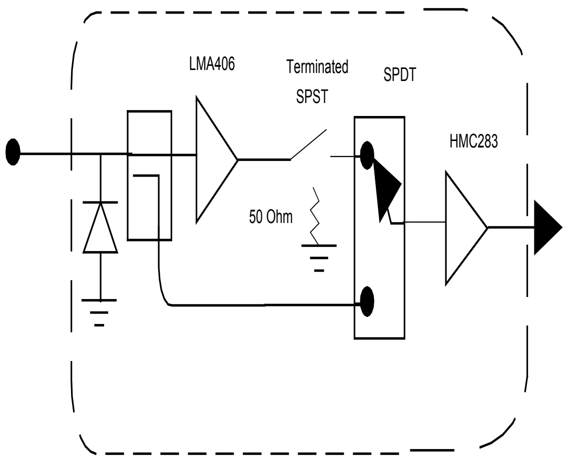


Figure 5: High gain Frontend block diagram

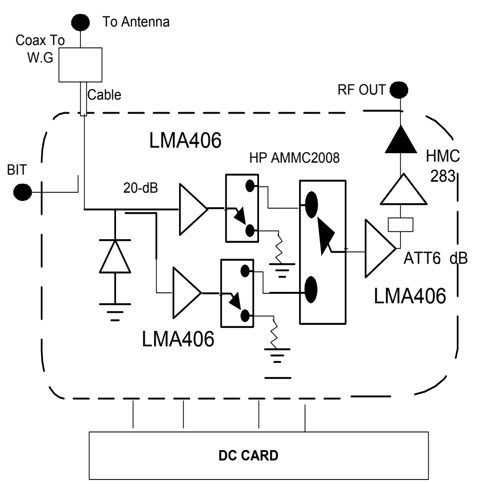


Figure 6: High gain Frontend block diagram with amplifier in the low gain channel

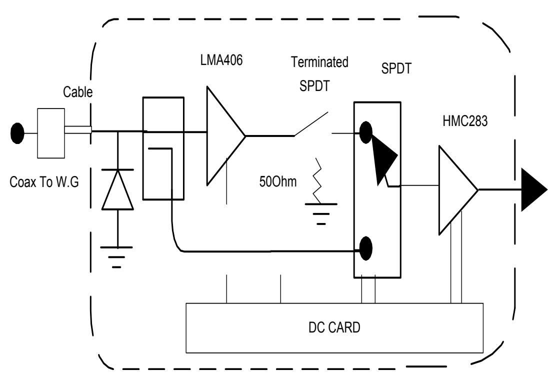


Figure 7: Detailed block diagram High gain Frontend High gain Front End Design

The high frontend electrical characteristics was evaluated by using ADS Agilent software and by using SYSCAL software. Figure 8 presents the frontend module noise figure and gain for LNA noise figure of 9.5dB. The overall computed module noise figure is 13.3dB. The module gain is 32.48dB. Figure 9 presents the frontend module noise figure and gain for LNA noise figure of 5dB. The overall computed module noise figure is 10dB. The module gain is 29.5dB.

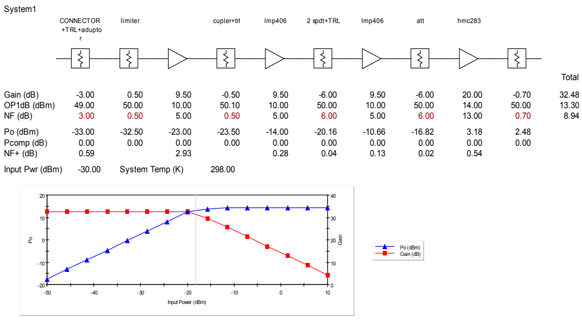


Figure 8: Frontend module design for LNA N.F=9.5dB

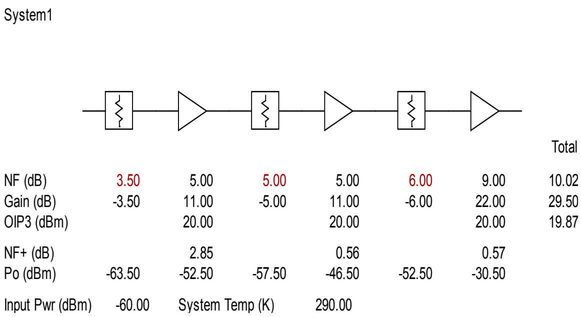


Figure 9: Frontend module design for LNA N.F=5dB

Measured results of frontend modules is listed in Table 6.4. HMC283 assembly is shown in Fig. 10. A photo of the frontend is shown in Fig. 11. There is a good agreement between computed and measured results.

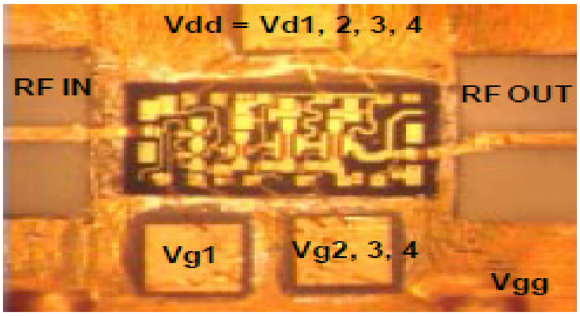


Figure 10: HMC283 assembly

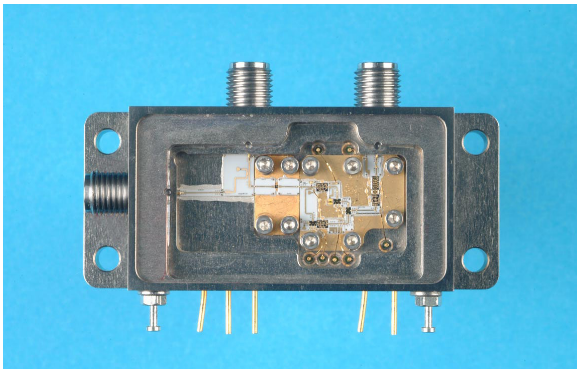


Figure 11: 18 to 40GHz frontend module

Table 6.4: Measured results of frontend modules

Parameter	DF6	DF4	DF3	DF2	DF1
High gain max	31	32	32.5	32.5	31
High gain min	26	26	27.5	27	26
High gain avg	29	29	29	29	29
Amp. Bal.	5	6	5	5	4
S11(dB)	4.5	5	5	5	5
S22(dB)	7.5	6	5	6	5
Isolation(dB)	9	9	10	10	6.5
Low gain max	19	18	17	17	17
Low gain min	13	10	7.5	12	12
Low gain avg	15	14	12	14	14
Amp. Bal.	6	8	9.5	5	5
P1Db 30GHz	11.6	11.93	11.7	11.4	10.9
P1Db 40 GHz	13.96	14.5	15.58	15.28	14
NF 30 GHz	8.68	9.48	8.65	8.45	10.5
NF 40 GHz	9.28	10.1	8.64	9.17	10.24

A photo of the compact wideband 18 to 40 GHz RF modules is shown in Fig. 6.16.

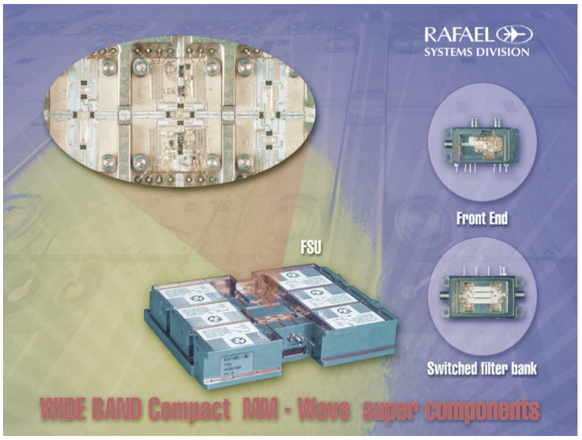


Figure 12: Photo of 18 to 40GHz compact modules

18 to 40 GHz Integrated Compact Switched Filter Bank Module

A wideband low cost integrated 18 to 40 GHz Compact Switch Filter Bank Module is presented. The switched filter bank consists of three channels. The filter consists of nine side coupled sections. Wide band MMIC switches are employed to select the required channel. The pass band bandwidth of each channel is around 8GHz. The Insertion Loss is around 12dB with +1dB flatness. The Rejection at +7GHz from center frequency is 40dB. The Rejection at +11GHz from center frequency is around 60dB. The Filter Bank dimensions are 20X50X10 mm.

A. DESCRIPTION OF THE FILTER BANK

The block diagram of the Filter Bank Module is shown in Fig. 13. The Filter Bank Module consists of three wideband filters. The filter consists of nine side coupled sections printed on a 5 mil alumina substrate. The filters input and output ports are connected to wide band MMIC SPDT switches via 1 to 2dB attenuators. The attenuators are employed to adjust each channel losses to the required value. The module losses are adjusted to be higher in the low frequencies and lower in the high frequencies. This feature improve the system flatness over the frequency range. The Filters are glued to the surface of the mechanical box. The input and output switches are assembled on a covar carrier. During development it was found that the spacing between the filters and the carrier should be less than 0.03mm in order to achieve +1dB flatness and V.S.W.R better than 2:1.

 ISSN - 2250-1991

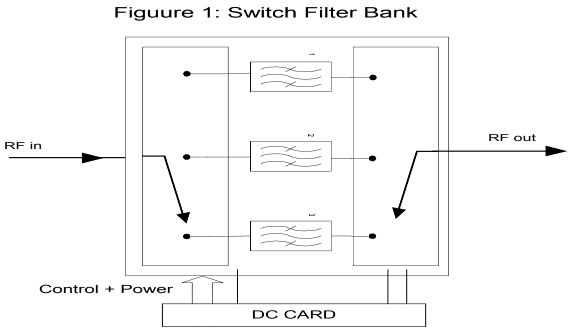


Fig. 13: 18 to 40 GHz Compact Filter Bank Module

B. Switch Filter Bank specifications

The switch filter bank specifications are listed in Table 5.

C. FILTER DESIGN

The filters have been designed and optimized by employing AWR and ADS Software. The filter consists of side coupled sections printed on a 5 mil alumina substrate. The sensitivity of the design to substrate tolerances such as height and dielectric constant has been optimized. The configuration that was less sensitive to production tolerances was fabricated. Fig. 14 presents the Filter Bank computed S parameters by using ADS software.

Table 5: Switch Filter Bank specifications

Parameter	Requirements
Frequency range	18-40.1GHz
Number of channels	3
Channel Pass band	8GHz
Rejection	40dB-min.@ F0±8GHz 50dB min @ F0±11GHz
Flatness	±1.2dB max. For 4GHz
I.L: CH-1 I.L: CH-2 IL: CH-3	12-14.5dB 10.5-13.5dB 9-12dB
Switching time	100nsec
Input Power	25dBm max
VSWR	2.5 :1 max
Control	2 LVTTL lines
Supply voltages	±5V DC. Heat dissipation - 1W max
Dimension	50X20X10 mm

Fig. 15 presents the filter bank S12 measured results in the production process.

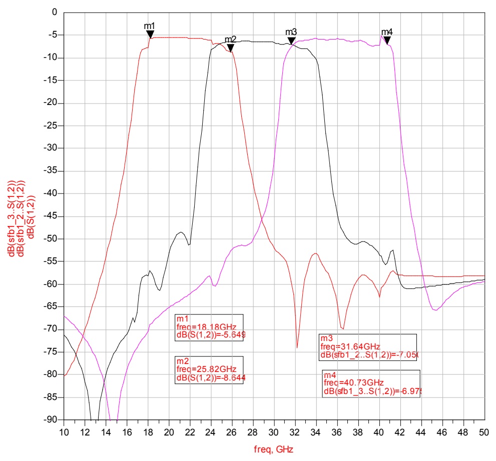


Fig. 14: Filter Bank computed S parameters

Fig. 16 is a picture of the SBF. We got a good agreement between the computed and measured results.

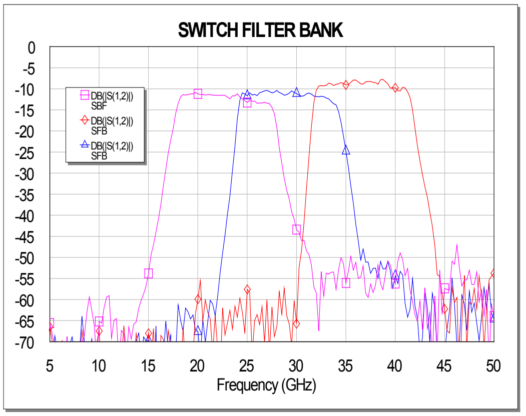


Fig. 15: Switch Filter Bank measured Results

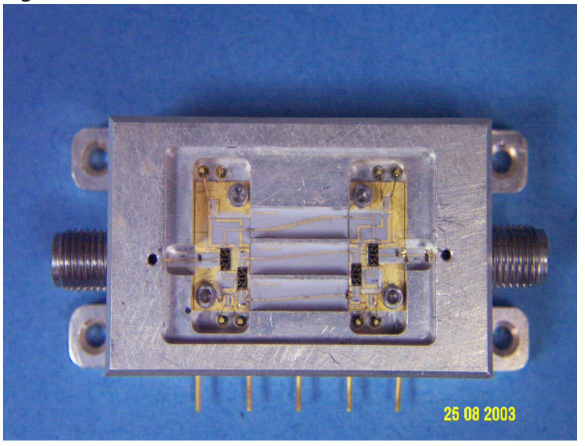


Fig. 16: Switch Filter Bank Picture

CONCLUSION

Several ultra-wideband RF modules are presented in this paper. Development and design considerations of a compact wideband 18 to 40GHz Front End and Switch Filter Bank Filter was described in this paper. The RF modules was designed by using ADS system software and momentum RF software. MMIC and MIC technology are used to develop wideband compact mm wave RF modules.

Dimension and losses of microwave systems are minimized by using Microwave Integrated Circuits, MMIC technology. MMICs are circuits in which active and passive elements are formed on the same dielectric substrate MMICs are dimensionally small and can be mass produced. There is a good agreement between computed and measured results.

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