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Design of Low Band Frequency Amplifier Using Different RF substrates

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***Abstract*— This paper presents design of a low band, fully integrated, amplifier(a Module in Homodyne Receiver) with a noise figure of less than 10dB, and also to attain signal flatness, circuit gain etc., The amplifier which generates the output signal in the analog form, there we consider the S11 & S21 parameters, These two parameters are crucial in defining the amplifier's circuit gain, signal flatness, noise figure. This amplifier is fabricated in broadband design using three different RF(Radio Frequency) substrates, each vary from one another in their performances.**

Keywords: Signal Flatness, Circuit gain, S-parameters(S11,S21), RF substrates.

Introduction

Entire 90º Field of View quadrant receiver covering 0.5-2.2GHz is integrated in a single mechanical housing using the state-of-the-art super component technology. Single and compact antenna array to measure the DF(Direction Finding) covering 0.5-2.2GHz frequency range. Advanced hybrid receiver uses the Homodyne down conversion principle which means deriving the LO(Local Oscillator) signal from the RF input signal. In Super hetero mode LO is given externally to the Receiver. Advanced hybrid receiver consists of 4 RF inputs to derive Direction of Arrival, Frequency and Amplitude. Direction of Arrival derived by using the BLI concept. Comparisons of phase angle of the incident signal between the RF paths are used to derive the Direction of Arrival. Frequency is derived from the inbuilt delay lines. Comparison of phase angle between the delay lines are used to derive the Frequency of the incident signal. Amplitude is derived by using the RF detector in the RF path. Mode Selection bits are used to select the mode (i.e., Homodyne, Channelizer and Super hetero mode) of the receiver. Channel selection is used to select the specific frequency band of operation in Channelizer and Super hetero modes. Input RF signal is amplified and given as RFPS out. All the features has been realized and then a development case has been made in this Paper.

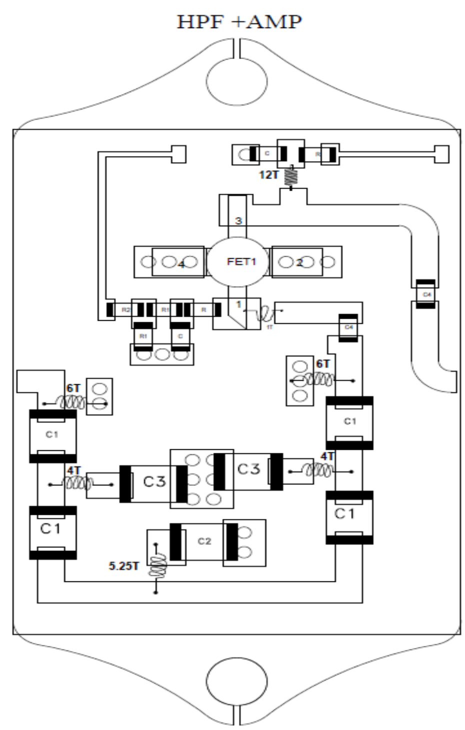

Fig. 1 Combination of HPF & Amplifier's Circuit Design

Challenges in Amplifier Design:

The receiver design presents challenges to designers because of its simultaneous need to achieve high gain, a low noise figure, high linearity, matched input and output, and unconditional stability with the least possible current consumption. Although all are equally important.

- Noise match vs. input gain loss
- Power consumption vs. noise figure & linearity
- Flatness of the signal gain
- Cost vs. performance

Different RF Substrates

The substrates used for this designs are application specific.

Generally we choose 3 types of laminates as substrates for the low band RF frequencies they are RO 4003, TMM(Thermoset Microwave Material), RT/Duroid

5880. The explanation below about each of these laminates gives us a good knowledge of application and the relevant substrate to be used.

a) RO 4003:

RO 4003 hydrocarbon ceramic laminates are designed to offer superior high frequency performance and low cost circuit fabrication. The result is a low loss material which can be fabricated using standard epoxy/glass processes offered at competitive prices. The selection of laminates typically available to designers is significantly reduced once operational frequencies increase to 500 MHZ and above. RO4000 material possesses the properties needed by designers of RF microwave circuits and matching networks and controlled impedance transmission lines.

Features & Benefits:

- Glass reinforced hydro carbon and ceramic
- Volume manufacturing process
- Excellent high frequency process
- Low Z-Axis expansion

Applications:

- Global Communication systems
- Wireless communication systems
- High reliability and complex multi layer circuits

b) ***TMM(Thermoset Microwave Material):***

TMM (Thermoset microwave material) is ceramic thermoset polymer composites designed for high plated thru-hole reliability strip line and micro strip applications. TMM laminates are available in a wide range of dielectric constants and claddings. The electrical and mechanical properties of TMM laminates combine many of the benefits of both ceramic and traditional PTFE microwave circuit laminates, without requiring the specialized production techniques common to these materials. TMM laminates do not require a sodium napthanate treatment prior to electro less plating. TMM laminates have an exceptionally low thermal coefficient of dielectric constant, typically less than 30 ppm/°C. The material's isotropic coefficients of thermal expansion, very closely matched to copper, allow for production of high reliability plated through holes, and low etch shrinkage values.

Features & Benefits:

- Wide range of dielectric constants. Ideal for single material systems on a wide variety of applications.
- Excellent mechanical properties. Resists creep and cold flow.
- Exceptionally low Thermal coefficient of dielectric constant.
- Coefficient of thermal expansion matched to copper. High reliability of plated through holes.

Applications:

- RF and Microwave Circuitry
- Global Positioning Systems Antennas
- Power Amplifiers and Combiners
- Patch Antennas
- Satellite Communication Systems

c) ***RT/Duroid 5880:***

RT/duroid® 5880 glass microfiber reinforced PTFE composites are designed for exacting strip line and micro strip circuit applications. Glass reinforcing microfibers are randomly oriented to maximize benefits of fiber reinforcement in the directions most valuable to circuit producers and in the final circuit application. The dielectric constant of RT/duroid 5880 laminates is uniform from panel to panel and is constant over a wide frequency range.

Its low dissipation factor extends the usefulness of RT/duroid 5880 laminates to Ku-band and above. RT/duroid 5880 laminates are easily cut, sheared and machined to shape. They are resistant to all solvents and reagents, hot or cold, normally used in etching printed circuits or in plating edges and holes. Normally supplied as a laminate with electrodeposited copper of ¼ to 2 ounces/ ft.2 (8 to 70µm) on both sides, RT/duroid 5880 composites can also be clad with rolled copper foil for more critical electrical applications. Cladding with aluminum, copper or brass plate may also be specified. When ordering RT/duroid 5880 laminates, it is important to specify dielectric thickness, tolerance, rolled or electrodeposited copper foil, and weight of copper foil required.

Features & Benefits:

- Lowest electrical loss for reinforced PTFE material
- Low moisture absorption
- Isotropic
- Uniform electrical properties over frequency

Applications:

- Commercial Airline Telephones
- Millimeter Wave Applications
- Military Radar Systems
- Missile Guidance Systems
- Point to Point Digital Radio Antennas

Factors	TMM	5880	4003
Thermal Coefficient εr	+37°c	+22°c	+40°c
Dielectric Constant Ɛr`	3.27±0.032	1.96±0.04	3.38±0.05
Thermal Expansion	15°c	44°c	11°c
Dissipation Factor	0.0020	0.0019	0.0021
Specific Heat	-40°c to +100°c	-55°c to 150°c	280°c
Peel of Strength	5.7mm	>4.0mm	1.05mm

Table: 1 Comparison of three RF substrates with Specifications

S-parameters

S-parameters treat the signal in terms of voltage waves for a reference impedance - the "system impedance" which is normally 50Ω.

The four s-parameters of a two-port represent the following transfer of power:-

S11: Reflected back from input

S21: Forward from the input to the output

S12: Reverse from the output to the input

S22: Reflected back from me output

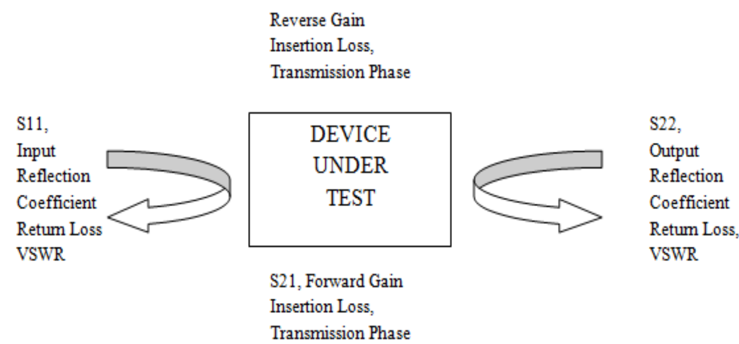

Fig 2: Working of S-parameters

Since the proportion of signal reflected back from (e.g.) the inputs depends on the input impedance on the two-port, so the S11 is closely related to the input impedance.

Three special cases are:

- Zero input impedance (**short** circuit): S11=-1 because all the signal is reflected, and the reflected voltage wave must be anti-phase an order to make the voltage at the short circuit zero.
- Infinite input impedance (**open** circuit): S11=+1 because all the signal power is reflected, and the voltage is a maximum at the open circuit.
- A **matched** input: This means that the input impedance is equal to the systems impedance, and leads to S11=0 (no reflected signal, all the power goes into the network).

Results:

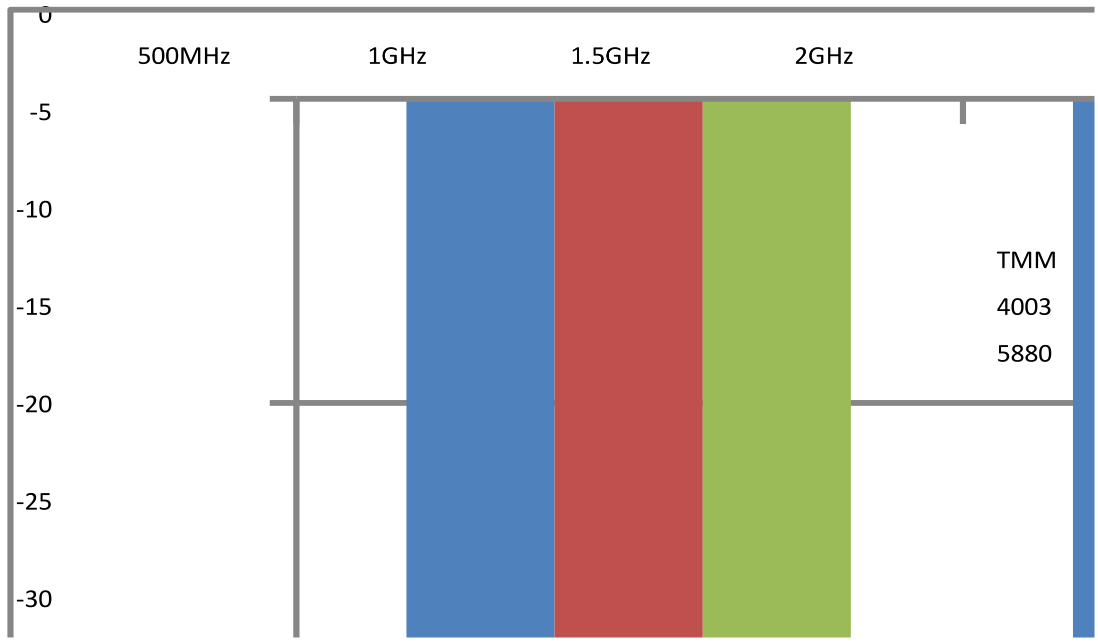

Fig 3: Bar representation for S11 parameters in different frequencies for different Substrates X-axis Gain in dB, Y-axis Frequency

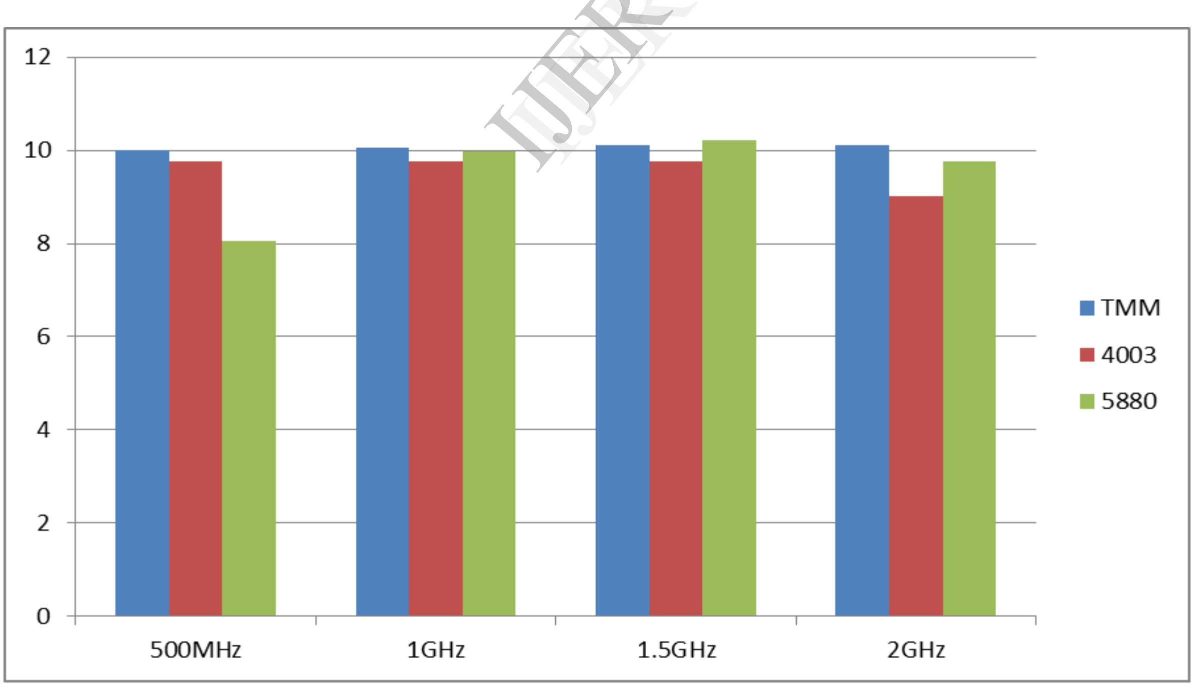

Fig 4: Bar representation for S21 parameters in different frequencies for three substrates X-axis frequency, Y-axis Gain in dB

Conclusion

The chart represents the performances of three RF substrates at different frequencies, by seeing the results we conclude that 5880 substrate performs good result in amplifier's design when compared to 4003 substrate. Theoretical values of the substrates are

TMM substrate the signal flatness is 0.08dB

4003 substrate the signal flatness is 0.378dB

5880 substrate the signal flatness is 0.23dB

The Signal Flatness can be calculated by the formula,

$$Flatness = (Gain_{maximum} - Gain_{minimum}) / 2$$

In the result shown that TMM substrate is good, but when compared to 5880, TMM is of very high in cost, its circuit stability is also low, and its temperature coefficient is 100^0C whereas 5880's temperature stability is up to 150^0C. by considering all those features we have chosen 5880 substrate for the design of Low band amplifier.

Future scope

In this paper the bandwidth is limited up to 2.2GHz, increase in bandwidth is extended to 4GHz, circuit stability is going to be increased by minimizing the acceleration, vibration, stress, etc. Miniaturization in circuit design and overall hardware design is in the process.

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