A NEW CONCEPT : AN ELECTRONICALLY TUNABLE MMIC FLATNESS CORRECTOR

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ABSTRACT

A novel concept resulting in a good insertion gain flatness in receiver applications is reported. The idea is based on inserting into a chain a device with an attenuation characteristic equal and opposite to the gain variation of the rest of the chain.

An electronically tunable flatness corrector composed of coupled lines controlled by varactors has been realized in the Ku-band. This idea has already been applied in a hybrid circuit which is used in a space telecommunication receiver. It is the first MMIC flatness corrector reported.

Insertion losses of 0.25 dB, dynamic correction of 1.5 dB and input/output return losses better than 15 dB have been measured.

INTRODUCTION

A receiver is a cascade of active or passive functions such as amplifiers, phase shifters, attenuators and mixers and this often induces transmission gain deformations (typically : "valleys", "hills" or slopes). Optimizing the overall gain flatness of a receiver results in long and expensive tuning of each stage.

There is an advantage to be gained in inserting in new receivers flatness correctors that present an opposite variation to the receiver gain, to obtain a good overall flatness.

For space applications, the correcting device must be miniaturized, without DC power consumption and electronically tunable in order to be remote-controlled and suitable for any kind of correction.

To demonstrate the feasibility of the idea, an electronically tunable flatness corrector has been developed as MMIC in the 10.7-12.75 GHz range. The circuit realized achieves typically more than 1 dB dynamic measured correction with input/output return losses better than 15 dB.

NEW CONCEPT DESCRIPTION

The concept of the corrector is based on a series two band-stop filters whose resonant frequencies are electronically tunable. Varying one of those frequencies makes the filter's absorption peak move. If the resonant frequencies are out of the 10,7-12,75 GHz range, the corrector presents minimal insertion loss. If the resonant frequencies are moved until beeing merged, the corrector presents a maximal magnitude "valley" in the band. Intermediate situations such as valleys moved in the frequency range or slopes, can be obtained by varying the two band-stop filters' resonant frequencies between those two extremes.

Realization of the electronically tunable band-stop filter

This filter is realized by two quarter-wavelength coupled lines controlled by two L.C parallel resonant filters with variable capacitors (fig. 1).

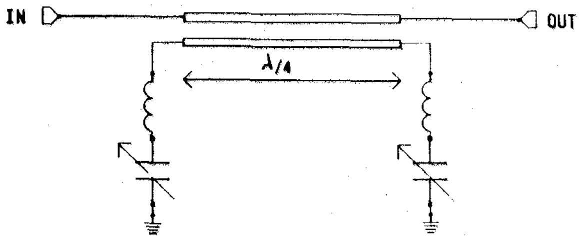

Figure 1 : Tunable band stop filter schematic

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Capacitor variation induces a load impedance variation of the filter and results in a shift of the resonant frequency.

L.C filter realization

An unbiased fet ("cold" fet) has been used to realize the L.C. circuit. Connecting together drain and source of the cold fet allows to get a varactor diode whose capacitance depends on the voltage applied to the gate (figures 2a and 2b).

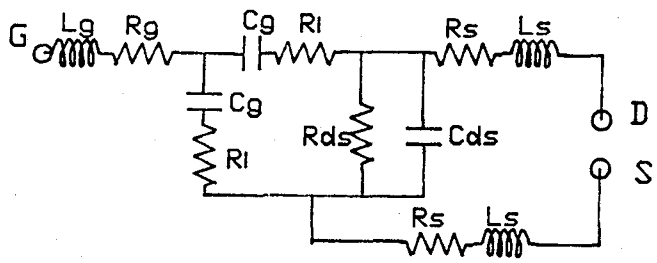

Figure 2a : cold fet schematic

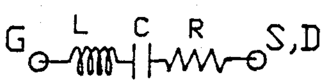

Figure 2b : varactor schematic
with C = 2 x Cg
L = Lg + Ls/2
R = (Ri + Rs)/2 + Rg

Such a MMIC varactor is equivalent to a serie L.C resonant filter including a voltage controlled capacitor. Adjusting the gate width of the fet allows to obtain a suitable inductance value and an appropriate resonant frequency.

In a nutshell, the tunable band-stop filter can be realized by using two quarter-wavelenght coupled lines controlled by two cold fets used as varactors.
Realizing the complete flatness corrector needs the cascading of two tunable band-stop filters (figure 3a).
In order to miniaturize the circuit, the two serial filters have been replaced by two parallel band-stop filters through the use of three quarter-wavelength coupled lines controlled by four "varactors" (fig.3b)

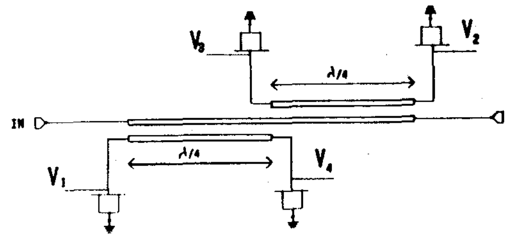

Figure 3a : tunable flatness corrector schematic

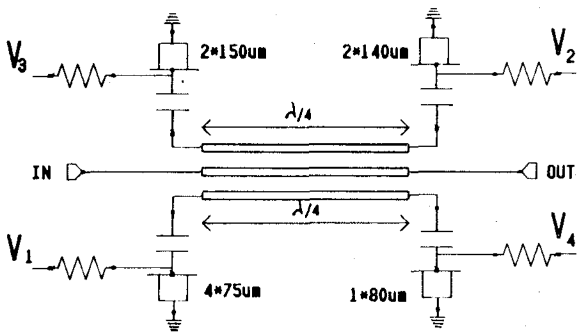

Figure 3b : final tunable flatness corrector schematic

KU-BAND FLATNESS CORRECTOR DESCRIPTION

To demonstrate the feasibility of the concept described above, a Ku-band electronically tunable flatness corrector has been realized as MMIC. The cold FETs' gate widths have been optimized to get the Cg x L product giving a proper filter frequency variation. As negative control voltages are applied through high value resistors (3 kΩ) to the gate of each cold fet used as varactor, no power is consumed.

Four DC block 1.3 pF capacitors located between coupled lines and "varactors" separate their respective bias and are taken into account in the capacitance value of each reasonant L.C circuit.

Simulation of this circuit was performed on a microwave circuit simulator with electrical models provided by the manufacturer. The three line coupler has been calculated to be centered around 11.5GHz. To reduce the circuit area, the three coupled lines have been bent.

The circuit was manufactured by THOMSON/DAG GaAs foundry. 0.5 μm gate-length MESFETs' were defined by E-beam writing. Cold fets used as varactors present 2 x 150 μm, 2 x 140 μm, 4 x 75 μm and 1 x 80 μm gate widths.

The processed wafer is 4 mils thick and 2 inches in diameter. The photograph of the fabricated circuit is shown on figure 4. Size is 2.3 * 1.3 mm^2.

EXPERIMENTAL RESULTS

The measured transmission and input/output return losses are displayed on figures 5 to 7. The gate voltage of each cold fet varies from - 2 V to 0 V.

If no correction is necessary, the insertion losses of the flatness corrector are less than 0.25 dB with input/output return losses better than 20 dB.

In any other configuration, tuning one or two control voltages allows to obtain a "downward" slope correcting an "upward" slope or a "valley" correcting an "hill" etc.. Maximum measured attenuation is 1.5 dB and input/output return losses are better than 15 dB.

The use of varactors, in this case formed by cold fets, guarantees that no DC power is consumed.

MANUFACTURING YIELD

This circuit has been processed together with other functions on a 2" wafer. 25 flatness correctors have been manufactured.

DC testing has been successfull for 23 circuits, corresponding to 92 % DC yield. RF acceptance criteria were : input/output return losses better than 15 dB and minimum attenuation better thant 0.5 dB in the frequency range. Among the 23 DC-good chips, 15 passed the RF screening, which corresponds to 65,2 % RF yield. The overall fabrication yield is then 92 x 65,2 = 60 %.

Figure 8 gives the distribution of transmission attenuation for the 15 RF-good chips, in one case of correction ("valley").

The spread in the results is very limited due to judicious choice of the circuit topology.

CONCLUSION

A new concept allowing to cancel transmission gain variations was proposed. The idea leans on the use of three quarter-wavelength coupled lines controlled by varactors.

This idea was applied in the realization of a MMIC in the Ku-band. The results measured on the manufactured chips proved the feasibility of this principle.

Excellent compactness, very low weight, tunability and insensitiveness to technological dispersions of fabrication, allow to use it for space applications such as receivers or active phased array antennae.

ACKNOLEDGEMENT

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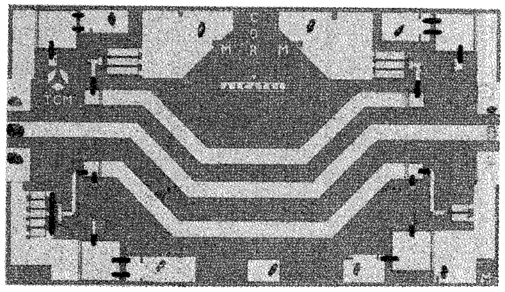

Figure 4 : photograph of the fabricated circuit

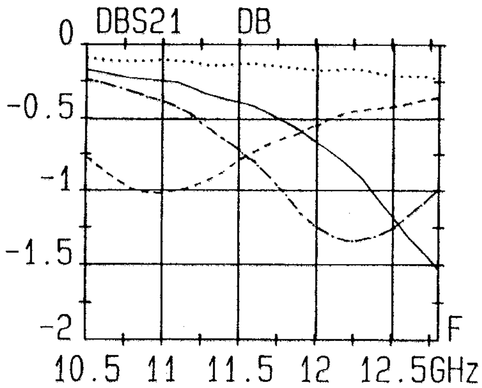

Figure 5 : Measured attenuation under different sets of bias conditions

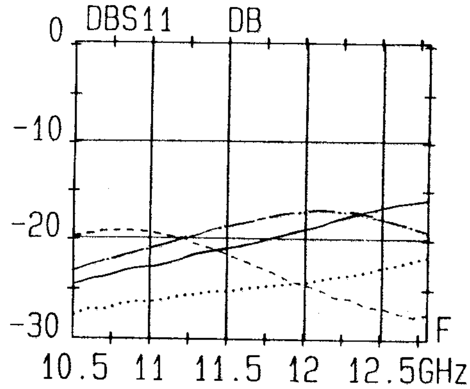

Figure 6 : measured input return losses under different sets of bias conditions

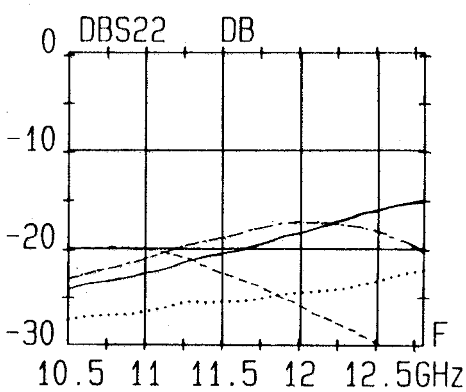

Figure 7 : Measured output return losses under different sets of bias conditions

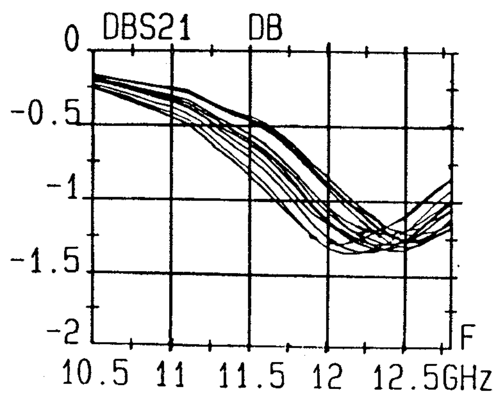

Figure 8 : Distribution of measured attenuation for 15 chips, under one set of bias conditions