A NEW APPROACH FOR THE DESIGN OF MICROWAVE OSCILLATORS AND FILTERS USING DIELECTRIC RESONATORS

ABELARDO PODCAMENI AND LUIZ F.M. CONRADO

CETUC - CATHOLIC UNIVERSITY OF RIO DE JANEIRO
22453 - RIO DE JANEIRO, RJ - BRASIL

ABSTRACT

A comprehensive model for the transmission-mode dielectric resonator coupled to microstrip line is given. New approach design for parallel feedback oscillators and bandpass filters are discussed. A low-noise oscillator and two different filters, using both the same hardware, are presented.

INTRODUCTION

Dielectric resonators, DR, have brought significant improvement on microwave oscillators and filters design {1}. Compactness, ligthweight,temperature stability and relative low costs are easily achieved.

For oscillators, active two-port devices - GaAs Fets and bipolar microwave transistors - are usually preferred for their efficiency. Microstrip technology is also preferred: integration is easily obtained.

For filters, integration is also possible. Designs using microstrip input and output lines have been related {2,3}.

Within the scope of oscillators,several basic configurations are possible. The DR may be placed whether at the output {4} or at the input {5} of the active device. However, broader tuning bandwiths are believed to be obtained if the DR works as a parallel feedback element. Ishiara et al {6} have presented a such design. More recently, Khanna {7} also used the DR as a parallel feedback element. Emphasis was put on obtained maximum values of the small-signal output reflection coefficient. Neither of theses two last mentioned papers dealt on controlling the total phase shift around the feedback loop.

Within the scope of bandpass filters, the papers usually relate a direct electromagnetic coupling from side-by-side DR' s{1,3,8}. In practice, the final distances between adjacent ressonators must be somewhat adjusted. For multipole filters - a large number of DR's - this adjustment becomes quite annoying as it disturbs the whole DR chain. An alternative approach has been proposed. Recently, Guillon et al {9} suggest using a simple - two pole - bandpass filter cascaded with two others bandstop filters. The skirtness of a higher order bandpass filter is then achieved.

In this paper a rather comprehensive model for transmission-mode DR will be presented. For the design of oscillators it will be possible to prescribe the magnitude and the phase of the feedback factor. Only the enough power will be routed from the output to the active device input port. Further, the feedback loop will present the suitable electric length for providing the correct phase composition. For the design of bandpass filters it will be possible to couple each DR to an individual microstrip section instead of a

0149-645X/85/0000-0169 $01.00 © 1985 IEEE

side-by-side DR arrangement. Spatial separation between the several DR's may lead to rather easy multipole design. No mutual interference between the DR's will be experienced. Each one is easily adjusted, either with respect to its own coupling factor or tuned with respect to its own resonance frequency.

MODEL PROPOSED

A model for the DR coupled to microstrip line and working at the transmission-mode has been previously presented {10}. This one, however, is limited for a particular situation; the distance, θ, from the DR the microstrip line edges is a quarter of a wavelength, like shown in FIG.1a.

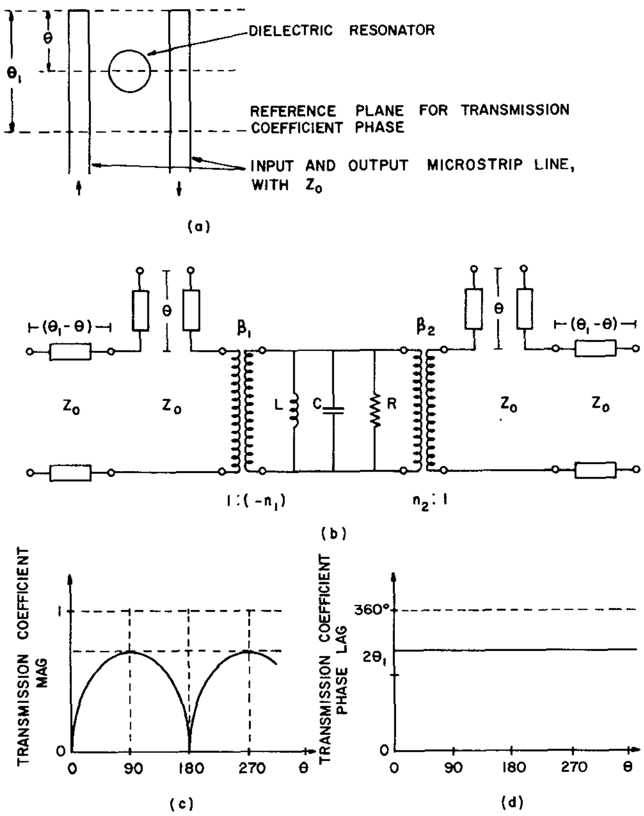

FIG.1: Transmission-mode dielectric resonator
(a) Layout using microstrip open lines and an arbitrary distance from open edges
(b) Equivalent circuit using open series stubs
(c) Transmission coefficient (magnitude) as a function of the distance from the open edges
(d) Phase of the transmission coefficient.

Now, the model will be extended to any value of θ. The equivalent circuit is presented in FIG.1b. When the amplitude response is measured with respect to θ, the results obtained are those depicted in FIG.1c: a continuous variation from a transmission zero up to a maximum value, occuring at $\theta=90^{o}$. This maximum value depends upon the coupling factors, β_1 and β_2, between the DR and the microstrip lines. On the other hand, for all θ, the phase response is shown to be constant, as it may be seen at FIG.1d. For the symmetrical case $\beta_1 = \beta_2$, the following equations describe the model, concerning the reflection and transmission coefficients

$$1/S_{21} = \{[1+(1/a)] + j[(Q'/a)+\cot\theta]\}.p$$

$$S_{11} = (1/p) - S_{21}$$

where $Q' = Q[(f^2/f_o^2)-1]$; $a = 2(\beta+1)\sin^2\theta$, the phase factor: $p = \cos 2\theta_1 + j \sin 2\theta_1$, f_o is the resonance frequency of the DR itself, while Q is the unloaded quality factor in the MIC enviroment.

OSCILLATOR DESIGN

By using the above described model an oscillator design is easily accomplished. It is a matter of providing access lines, from input and output of the active device, in a way that the total phase shift is an integer multiple of 2π. The active device transmission coefficient, S_{21}, is included in this computation, together with that of the DR. The magnitude loop gain is also easily made slightly greater than the unity, by using a suitable value of θ. It is interesting to remember that further small θ adjustments will not interfere with the loop phase shift, rather only with the gain value.

In practice, the S_{21} small signal value may be used, as first approximation, for zero phase shift loop computation. Here, two 4 GHz MIC oscillators, using the same bipolar transistor - NEC 56708D - are offered as examples. Schematic layout is the one of FIG.2. Two different feedback factors were used.

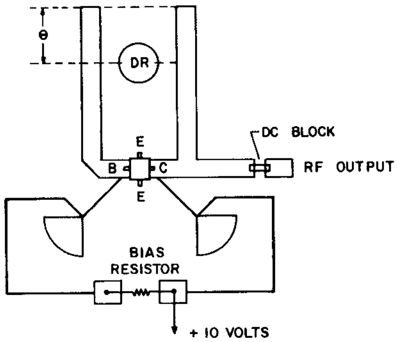

FIG.2: Typical layout of a feedback DR stabilized oscillator

Results obtained are those given in Table 1.

Nominal feedback factor	Power output	Tunabi-lity	Efficiency	FM noise at 10 KHz
-5dB	+19dBm	80MHz	27%	-100dBc/Hz
-2dB	+13dBm	300MHz	20%	- 95dBc/Hz

Table 1: Summary of results obtained with 4GHz parallel feddback oscillators using the feedback factor as a parameter.

It may be seen that with a loose feedback coupling factor a quite high efficiency is obtained. FM noise, at center of tuning band, is very good and comparable with those recently obtained {11, 12} when no special features for noise reduction are considered. By using a tighter feedback factor the tunability range may be increased at the expense of decreasing the efficiency. In any case, a noise deterioration was experienced at band edges.

FILTER DESIGN

Within the scope of the above described model, and keeping θ as a parameter, it is easy to characterize the DR with respect to its slope parameter {13}. The filter design is the easily accomplished by quite classical methods. Simple λ/4, or 3λ/4, lines are used as impedance inverters. A three-element filter may present an aspect like shown in Fig.3. If the central passband

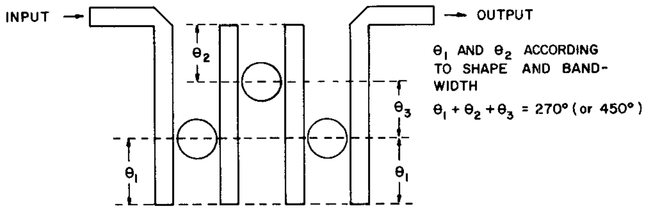

FIG.3: Typical layout for a three-element DR microstrip coupled bandpass filter.

frequency is kept constant, then small variations of the θ's involved may somewhat modify shaping and bandwidth. Two examples are furnished, centered at 8220 MHz. The first is a 50MHz bandwidth, 1dB ripple Chebyshev design, and its performance is shown in Fig.4 - solid line. The second

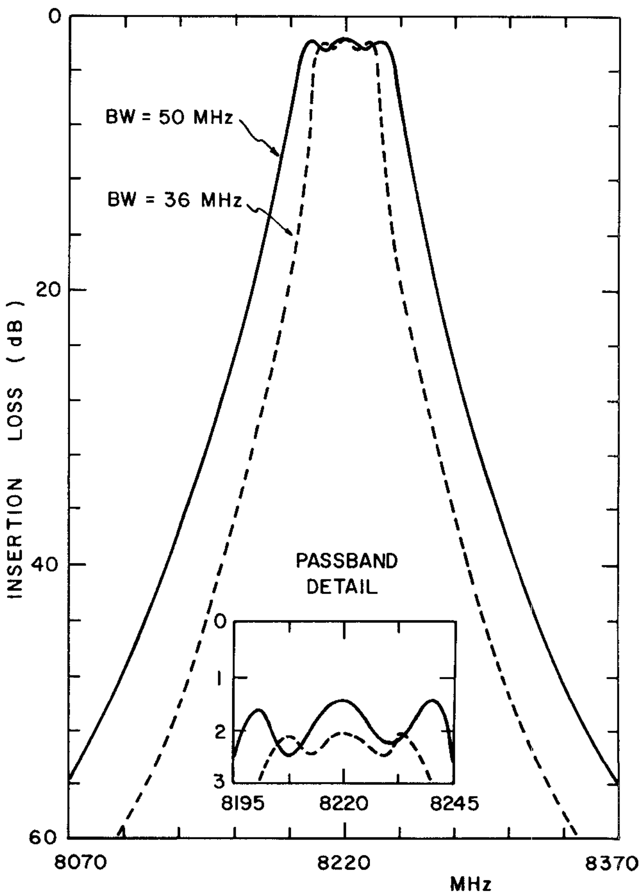

FIG.4: Three-element DR bandpass filters: results obtained with two different designs using the same hardware.

is an 36MHz bandwidth, 0.5dB Chebÿshev shaped, shown in the same figure - dashed line. In both cases the same hardware was used and tuning was easily accomplished. A number of other trial filters were built. Within this simple approach - of using 50Ω impedance inverters - it was observed that bandwidths from about 2% to 0.3% are obtained. The narrower the bandwidth the greater the insertion loss. Within that mentioned ranges, typical figures are about 0.2 to 0.7 dB per resonant element, respectively.

CONCLUSIONS

From a comprehensive model for the transmission - mode DR coupled to microstrip lines, parallel feedback oscillators and bandpass filters were obtained. Oscillator design mainly takes into account zero phase-shift loop considerations as in classical low frequency design: a rather easy approach. Filter design is favoured by the DR spatial separation. Flexibility is added as the same hardware may support different passband shapes and bandwidths.

ACKNOWLEDGEMENTS

This work was supported by Telecomunicações Brasileiras S.A. under the contracts 88/80 and 28/83.

REFERENCES

{1} J.K.PLOURDE and C.REN - "Applications of Dielectric Resonators in Microwave Components", IEEE Trans. on Microwave Th. and Techn., Vol.MTT-29,No.8, Aug. 81, pp. 754-770.

{2} D.J.MASSE and R.A.PUCEL - "A Temperature-Stable Bandpass Filter Using Dielectric Resonators", Proc. IEEE, Vol.60, June 72, pp. 730-731.

{3} J.D.IVELAND - "Dielectric Resonator Filters for Applications in Microwave Integrated Circuits", IEEE Trans. on Microwave Th. and Techn., Vol. MTT-19, No.7, July 71, pp.643-652.

{4} H.ABE, Y.TAKAYAMA, A.HIGASHISAKA and H. TAKAMIZAWA - "A Highly Stabilized Low-Noise GaAs FET Integrated Oscillator with a Dielectric Resonator in the C-Band", IEEE Trans. on Microwave Th.and Techn., Vol. MTT-26, No.3, March 78, pp. 156-162.

{5} A.PODCAMENI and L.A.BERMUDEZ - "Large Signal Design of GaAs FET Oscillators Using Input Dielectric Resonator",IEEE Trans. on Microwave Th. and Techn.,Vol. MTT-31, No.4, April,83, pp.358-361.

{6} O.ISHIARA,T.MORI,H.SAWANO and M.NAKATANI - "A Highly Stabilized GaAs FET Oscillator Using a Dielectric Resonator Feedback Circuit in 9-14GHz",IEEE Trans. on Microwave Th. and Techn., Vol.MTT-28,No.8, Aug. 80, pp.817-824.

{7} A.KHANNA - "Parallel Feedback FETDRO Design Using 3-Port S-Parameters", in IEEE MTT-S Digest, 1984, (San Francisco),pp.181-183.

{8} S.B.COHN - "Microwave Bandpass Filters Containing High-Q Dielectric Resonators", IEEE Trans. on Microwave Th. and Techn., Vol.MTT-16, April 68, pp.218-227.

{9} P.GUILLON,M.P. CHONG and Y.GARAULT - "Dielectric Resonators Bandpass Filters with High Attenuation Rate" in IEEE MTT-S Digest,1984, (San Francisco), pp. 240-242.

{10} B.A.GALWAS - "Scattering Matrix Description of Microwave Resonators", IEEE Trans. on Microwave Th. and Techn., Vol.MTT-31, No.8, August 83,pp.669-670.

{11} H.ROHDIN,C.SU and C.STOLTE - "A Study of the Relation Between Device Low-Frequency Noise and Oscillators Phase Noise for GaAs Mesfets" in IEEE MTT-S Digest, 1984, (San Francisco),pp.267-269.

{12} M.J.BIANCHINI,J.B.COLE,R.DIBIASE, Z. GALANI,R.W.LATON and R.C.WATERMAN JR. - "A Single-Resonator GaAs Fet Oscillator with Noise Degeneration" in IEEE MTT-S Digest,1984, (San Francisco), pp.270-273.

{13} G.L.MATTHAEI,L.YOUNG and E.M.T.JONES - Microwaves Filters Impedance Matching and Coupling Structures, New York: McGraw-Hill,1964.