FACTA UNIVERSITATIS (NIŠ)
Series: Electronics and Energetics vol. 9, No.1 (1996), 35–42

# MICROWAVE TV-FM TRANSCEIVER WITH INTEGRATED UNIPLANAR RF PART AND ACTIVE ANTENNAS

**Aleksandar Nešić and Siniša Jovanović**

**Abstract.** This paper presents a concept and realization of a low-cost microwave module of TV-FM transceiver for transmission of a composite TV signal (a video signal and a number of audio signals) with frequency modulation at $X$ band. Microwave part of the transceiver consists of a common oscillator, mixer and active receiver and transmitter antennas. All circuits and elements of the microwave part of transceiver are integrated on one side of the dielectric substrate (uniplanar structure) of dimensions $80 \times 25 \times 8mm$. Composite TV signal is brought to varicap diodes. IF signal is brought to a standard satellite receiver.

## 1. Introduction

Microwave part of the transceiver includes a voltage controlled oscillator (VCO) which is used as a transmitter and as a local oscillator of the receiver. In transmitting mode, VCO is being modulated by a composite TV-signal (with video signal and subcarriers of audio signals). Transmitter antenna, realized as a dual-loop printed antenna, is placed in the drain circuit. In receiving mode, VCO serves as a local oscillator of the receiver, while local oscillator signal is being taken from the gate circuit of the VCO.

Mixer of the receiver is integrated with active receiver antenna (printed dipole). The mixer is realized with two beam-lead Schottky diodes.

Signal from the local oscillator, i.e. from the gate of the FET of the oscillator, is led through high-pass filter to the mixer with active antennas.

---

Manuscript received April 21, 1995.
A version of this paper was presented at the second Conference Telecommunications in Modern Satellite and Cables Services, TELSIKS'95, October 1995, Niš, Yugoslavia..

The authors are with Institute of Microwave Techniques and Electronics, 11070 Beograd, Lenjinov Bulevar 165b.

IF signal from the mixer is led through low-pass filter to the satellite TV receiver.

All circuits of the microwave part of the TV transceiver with active antennas are realized in Three Coplanar Strips technique (TCS) on the Teflon fiberglass dielectric substrate of $h = 1.14mm$ thickness.

In order to obtain desired radiation pattern of the active antennas, behind the dielectric, at the distance of $7.8mm$, there is a reflector plate. Transmitter and receiver antenna have linear, but mutually crossed polarization.

VCO stability is better than $\pm 3\ MHz$ in the temperature range ($0°C - 45°C$), so the IF frequency is in range of AFC regulation of the satellite receiver. Microwave TV-FM transceiver operates alternately, either upon receiving or transmitting.

## 2. Oscillator

The oscillator is designed in TCS technique, thus enabling easier integration with active antennas [1]. The basic configuration of the oscillator is shown in Fig. 1 (a). For designing of the FET oscillator configuration, small signal $S$-parameters are used. The analysis is performed by using Eesof's Touchstone program package [2].

During the simulation, the best results are obtained using the MESFET NE72089A transistor [3]. By using this transistor, oscillation condition is accomplished by optimization of reactance in the source circuit, thus maximizing the reflection coefficient at the drain and at the gate at operating frequency ($9.5\ GHz$). Beside the oscillation condition at operating frequency, at lower frequency there is yet another oscillation condition. However, this undesired condition is suppressed by RF chocks in the gate and drain circuits.

In the next step, voltage controlled changing of the oscillation frequency is simulated with tuning diodes, Fig. 1(b). $C_v$ and $C_v'$ represent the capacitance of tuning diodes; $L$ and $L'$ parasite inductance of wires bonded on the chip capacitor ($8.2pF$); lines with lengths $l_1$ and $l_1'$ represent distances between the tuning diodes and the source and lines with lengths $l_2$ and $l_2'$ distances between the capacitor and the and of the short circuited line.

Length of short circuited TCS lines in the source circuit is $129°$. Two tuning diodes are placed at distance of $38°$ from the source (Fig. 2). Chip tuning diodes CKV2010-21 are used. Polarization of both gate and drain are realized through RF chocks with bonded gold wires $\phi = 17\mu m$, length $\lambda/4$, placed between by-pass capacitor and lines in the gate and drain circuits.

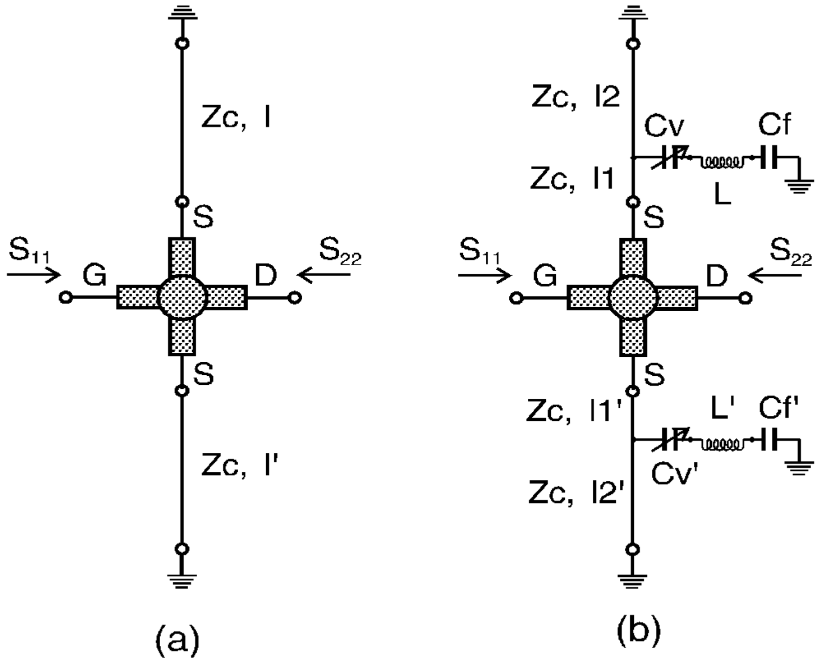


*Fig. 1. Configuration of the oscillator:*
*a) for fixed oscillation frequency*
*b) for voltage controlled oscillation frequency*

## 3. Transmitter antenna

Transmitter antenna is placed in the drain circuit of FET oscillator Fig.2. Dual-loop printed antenna is used, [4]. Behind the dielectric substrate on which the whole module is placed, at the distance of $\lambda_0/4$, there is a reflector plate in order to form desired antenna radiation pattern, of both transmitter and receiver. Influence of the reflector plate on the rest of the structure is negligible. Wave polarization of the transmitter antenna is marked by an arrow on Fig.2. In analysis of the dual-loop printed antenna, the cylindrical antenna equivalence concept is used, [5]. The original structure (strips on dielectric substrate) is transformed into equivalent structure consisting of circular cross section cylindrical conductor with dielectric cover. Then, this structure is transformed into equivalent structure with circular cross section, but with magnetic cover and changed diameter. The structure obtained in such way is analyzed as a wire structure with distributed inductances, using known methods.

## 4. Mixer with an active antenna

The local oscillator signal is led from the gate of the common oscillator through high-pass filter (also realized in TCS technique) to the balanced mixer with active antenna, Fig.2. The mixer diodes are connected to the ends of printed strip dipole. Diodes impedances are obtained using $3mA$ self-bias model. The printed dipole dimensions are optimized so that the dipole impedance at central frequency ($9.5\ GHz$) is conjugated to the impedance of two diodes connected in series. In such a way the best matching is accomplished. IF signal from the mixer is led through low–pass filter (also realized in TCS technique) to the output connector. On both sides of the receiver antenna (to the oscillator and to the IF output), at the distance of $\lambda/4$, there are air bridges placed between outer strips of TCS. In this way, at the place of mixer diodes, it is obtained that, for the receiving signal, outer strips of TCS behave as balanced coplanar strips - CPS, while the middle strip is on zero potential.

In analysis of the receiver antenna, the same method as in the case of the transmitter antenna is used.

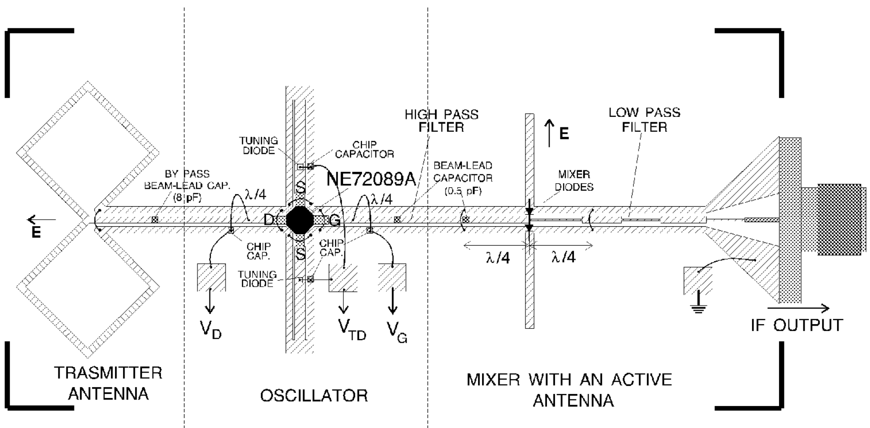


*Fig. 2. Circuit diagram of integrated uniplanar oscillator-transmitter and mixer with active antenna*

## 5. Realization

The whole integrated module is realized on Teflon-fiberglass dielectric substrate ($\varepsilon_r = 2.17, h = 1.14mm$), in TCS technique *6*. Width of all three strips is $0.5mm$, apart from short circuited lines in the source where inner strip is $1mm$ wide. All gaps are $50\mu m$ wide. Ground equalizing bond wire air bridges are installed around the gate, drain and two source terminals to ensure that all odd modes are excited on the TCS lines. RF chocks for oscillator transistor gate and drain biasing are realized in gold wires of $\phi = 17\mu m$ connecting by- pass chip capacitors and strips in gate and drain circuits.

The oscillation frequency versus voltage at tuning diode is shown in Fig. 3. It can be seen that range of linear frequency change is about 160 $MHz$, with slope of 12.5 $MHz/V$. The figure also shows the output power change in the whole range of frequency change. Total power change is less than $\pm 0.5$ $dB$. Oscillator frequency change versus temperature is presented in Fig. 4. Figure 5 presents symbolic block scheme of a link of two TV-FM transceivers.

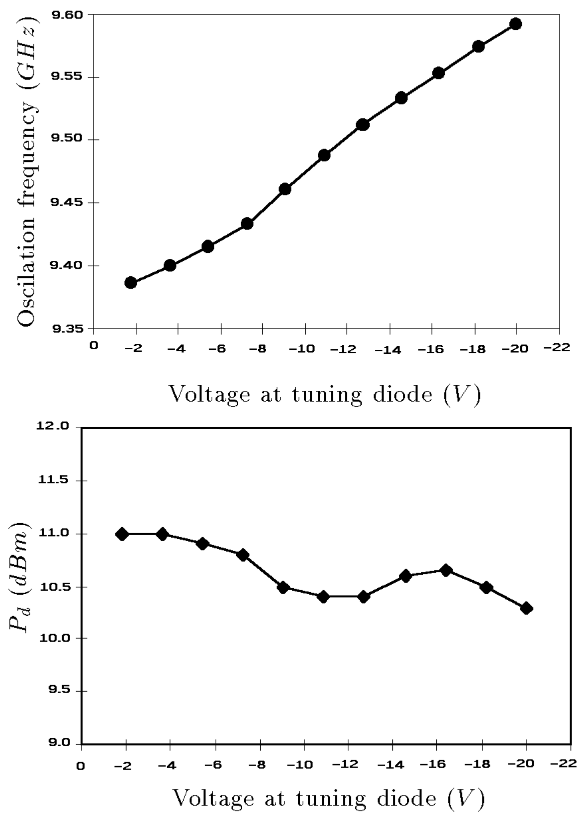


*Fig. 3. Oscillation frequency versus voltage at tuning diode and output power at drain circuit versus voltage at tuning diode, respectively*

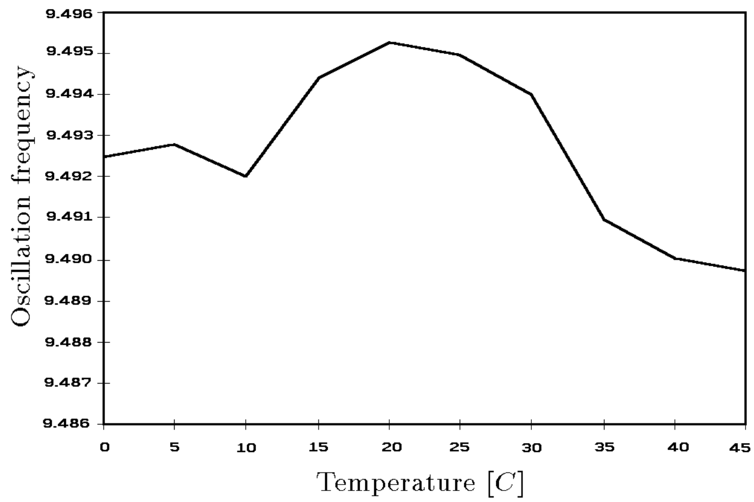


*Fig. 4. Oscillation frequency versus temperature*

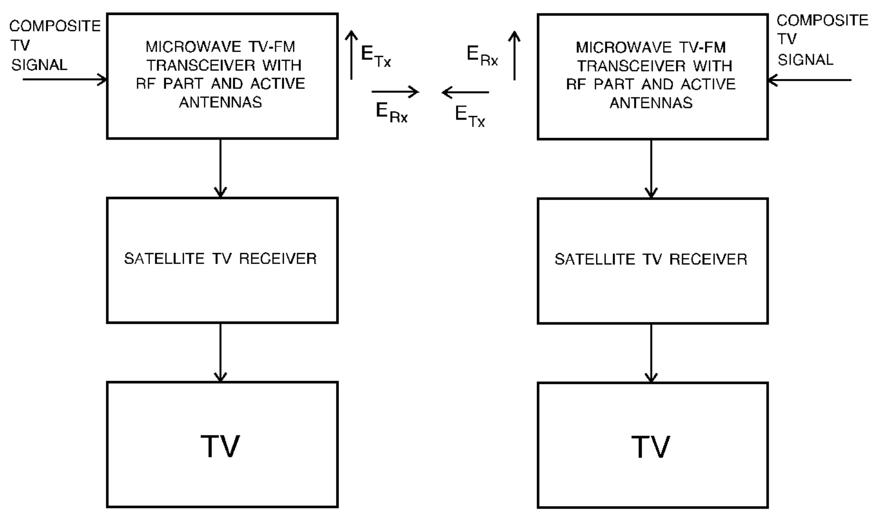


*Fig. 5. Block scheme of a link of two TV-FM transceivers*

## 6. Experimentally obtained results

| | |
|---|---|
| Central frequency | $f_0 = 9.5\ GHz$ |
| Total oscillator frequency change (Fig.3) | $\Delta f = 200\ MHz$ |
| Oscillator frequency change in linear part (Fig. 3) | $\Delta f_L = 160\ MHz$ |
| Frequency change with controlling voltage (linear part) | $\Delta f_L / \Delta V_L = 200\ MHz$ |
| Transmitter output power | $P_{T_x} = 11\ dBm$ |
| Transmitter power change in the whole range of frequency change (Fig. 4) | $\Delta P < 0.6\ dB$ |
| Isotropic Conversion Loss | ICL= 1.5 $dB$ |
| LO power (in the gate circuit) | $P_{LO} = 9\ dBm$ |
| Drain biasing | $V_D = 3V$ |
| Drain circuit | $I_D = 30mA$ |
| Efficiency | $\eta = 23\%$ |

## 7. Conclusion

Miniature, integrated uniplanar microwave part of the TV-FM transceiver with active receiver and transmitter antennas is investigated, designed and realized in Three Coplanar Strips technique. Composite TV signal with tone subcarriers is brought to the transmitter input ($V_{TD}$). IF signal from the receiver is led to the standard satellite TV receiver.

As the transmitter has wide range of linear frequency change, it can be used in transmission of high resolution video signals.

The same concept and design methods can be applied in realization at higher microwave and millimeter-wave frequencies.

## Acknowledgment

Authors would like to thank the Serbian Science Foundation for the financial support, Mr. M. Tasić and Ms. M. Marjanović for realization of the model and Ms. Nevena Španović for her help in translation of this paper into English.

### REFERENCES

1. Radnović I., Jovanović S., Nešić A.: *Naponski kontrolisan oscilator u tehnici koplanarnih vodova.*, XXXIX Konferencija ETRAN-a, Zlatibor, jun 1995.
2. Touchstone & Libra Reference: *(Ver 2.1).* Westlake Village, Eesof, Inc, 1990.
3. MICROWAVE GaAs DEVICES: *Cal.East.Lab.*. Santa Clara, California, 1990.
4. Nešić A.: *Printed dual-loop antennas fed by Three Coplanar Strips-TCS.* Institute of Microwave Techniques and Electronics, Internal publication, Beograd, 1994.

5. Popović B.D. and Nešić A.: *Generalization of the concept of equivalent radius of cylindrical antennas.* IEE Proc.H, 1984, 131, (3), pp. 153-158

6. Wadell B.C.: *Transmission Line Design Handbook.* Artech House, 1991.