Abstract: In the current work a complete transmitting and receiving system is constructed, consisted of oscillators, modulators, amplifiers, filters, envelope detectors and antennas. The carrier frequency was selected to be 2.45 GHz and the transmitted information had a bandwidth of a few kHz (voice). However much higher frequencies could be transmitted. The system was tested to be functional using a low frequency signal generator with an upper audio frequency of 10 kHz. The transmission of a real time analogue signal was successfully demonstrated with the use of a microphone.

Key-Words: Transmitting and receiving system; microwave transmission; carrier frequency; testing.

1. Introduction

Aim of the paper is to demonstrate the testing of a transmitting and receiving system and thereafter the transmission of an analogue signal using amplitude modulation (AM). The constructed system includes: a voltage controlled oscillator (VCO), a modulator, RF amplifiers, a diode detector, an audio amplifier and an audio power amplifier. A key of determining the quality of the work was to measure its degree of conformance to specifications. The frequency of transmission was lying in the license free range of the spectrum produced by an oscillator with no harmonics being present. A monolithic amplifier performed the modulation of the low frequency signal. The biasing circuit of the amplifier was designed according to the datasheets provided. In order maximum efficiency to be achieved the circuitry was first simulated on a CAD package, applying microwave design and then proceeded to the construction. The system worked satisfactory and transmission of information using amplitude modulation was well demonstrated.

2. Transmitting and receiving system

The schematic of Figure 1 shows in detail the arrangement of the devices, that consist the testing circuit (i.e., transmitting and receiving system). More analytically:

a. Oscillator: A Voltage Controlled Oscillator (VCO) was chosen from the Mini-Circuits catalogue instead. That was the JTOS-3000, which has wide frequency range, linear tuning characteristics, excellent harmonic suppression and low phase noise. It had 14 pins and its actual dimensions were (a)×(b)×(c) = 20.04×13.13×6.35 (mm). Pin 2 was used for the power supply (V_in) and pin 5 for the tuning voltage (V_tune). The microwave output was taken at pin 13 (V_out).

b. Modulator amplifier: As for the oscillator the RT/duroid® 5880 substrate was chosen. The amplifier had a 50Ω input and output impedance. Therefore the micro strip lines had the same width as for the oscillator case, w = 2.434 mm.

c. Filter of the transmitting system: A band pass filter can be constructed [7] from a series of micro strip resonators positioned so that adjacent resonators are parallel to each other, as mentioned earlier. The main characteristics of the filters are Substrate RT/Duroid® 6010.5, (εr) = 10.5, thickness (h) = 1.575 mm, Micro strip parallel-coupled band pass filter, Chebyshev frequency response characteristic, Pass band ripple not greater than 0.01 dB, Centre frequency of 2.45 GHz, Pass band ripple bandwidth of 4% (i.e. from 2.401-2.499 GHz) [7].

d. Antennas: This antenna is a quarter-wavelength long [1], laying vertically above a perfect ground. It has the same characteristics as a half-wave vertical dipole, because a perfect ground will produce a mirror image of the quarter-wave, a
result of the reflected radio waves as shown in the figure. When used with a perfect ground, the input impedance of the quarter-wave antenna is about 36Ω, which makes an acceptable impedance match for a 50Ω coaxial transmission line [1].

e. **Filter of the receiving system:** The filter employed was a four-pole filter since a sharp cut-off response was required. The specifications of the filter were set arbitrarily: Butterworth response with a gain of 20dB cut-off frequency at 10kHz and attenuation of 80dB at 100kHz [8].

f. **Power amplifier:** There was a large amount of audio power amplifiers available in the market. The LM380N 14-pin dual in line package was chosen, which required very few external components to make a complete 2.5W power amplifier with a load of 8Ω. The following configuration was implemented.

### 3. Testing of the system

The transmitting antenna was placed 40cm away from the receiving one. All individual devices were connected to the same ground point. The several biasing circuits were checked that they were providing the required voltages at the corresponding points. The dc voltage was set appropriately to obtain a voltage of 3.1 Volts at pin 3 (output) of the modulator. That voltage should not exceed this value since the maximum voltage allowed at pin 3 was 4.1 Volts.

A sinusoidal signal was applied at the modulator (pin 3) with peak to peak voltage of 2 Volt (1V amplitude) and a frequency of 2 kHz. This signal was obtained from the Function Generator, which had also the ability to regulate the dc voltage. The output of the modulator was amplified, passed through the band pass filter and then through a coaxial cable to the transmitting antenna. The output of the modulator was checked with an oscilloscope to see if the amplitude modulating signal remained as adjusted from the generator. It was observed that the signal experienced attenuation, due to loading, since its voltage amplitude was found to be 0.7 Volts. Therefore the amplitude of the signal was increased (from the generator) until the detector output was showing 2V peak-to-peak.

At the receiving end, the signal passed through the RF amplifiers, the band pass filter and the Envelope Detector. That was the point where the signal could be recorded, since the RF signal was out of the range of the oscilloscope, to be recorded at a previous stage.

The signal was experiencing the gain of the transmitter amplifier $G_{amp1}$, of the receiver amplifiers $G_{amp2}$ and $G_{amp3}$ but it also was attenuated by the filters $A_{filter1}$ and $A_{filter2}$. Therefore the pure amplification was given according to equation (1):

$$G_{amp1} + G_{amp2} + G_{amp3} - A_{filter1} - A_{filter2} = 4.15dB + 4.15dB + 4.15dB - 3.91dB - 3.58dB = 4.96dB$$  \(1\)

where $G$ stands for gain and $A$ for attenuation.

Figure 2 shows the input modulating signal and the envelope detector output. It can bee seen that the signal had an amplitude of 40mV. The noise imposed on the signal was either due to external noise, but mainly due to the carrier. The signal was fed into the active low pass filter which was set to have a gain of 15. Figure 3 shows the output of the filter where clearly the signal was smoothed out. Only the low frequency component was left i.e. the frequency of interest. At the output of the filter the amplitude was 630mV i.e. the gain was $G = \frac{630mV}{40mV} = 15.75$, approximately as expected. However the signal was imposed on a dc signal of 0.6 V.
That signal would cause saturation to the power amplifier. The solution was to insert a capacitor in series with the filter so that the dc signal would be blocked. A 470nF capacitor was chosen which would provide an impedance of 338Ω for a 1kHz signal and 33.8Ω for a 10kHz signal. Both impedances were considerably low, so that the performance would not be affected.

Finally, the signal was fed into the power amplifier which had an inherent gain of 50 (i.e. 34dB). The amplitude was increased to 14Volts. That gave a gain of $G_p = \frac{14}{0.630} = 22.22$ which was not as expected. An attempt to increase the gain was made but it remained the same.

At the output of the LM830, a miniature speaker was connected. Its output power was 0.3W and had an impedance of 8Ω. The sinusoidal signal applied to it produced a sound which could be altered by the tone control resistor RV1 of the power amplifier.

**4. Microphone coupling**

The idea was to transmit voice from one end to the other. In order to couple the voice signal to the modulator, a miniature PCB mounting encapsulated audio frequency transformer 1:1 ratio was bought. This was connected to the modulator as shown in Figure 4.

The microphone produced a low signal, which needed to be amplified. An LM741 was constructed in its non-inverting amplification mode shown in Figure 5 and 6.

The gain was set to be approximately 100 by setting the variable (200kΩ) resistor $R_2 = 100kΩ$ and $R_1 = 1kΩ$. Therefore:

$$G_{\text{mic}} = 1 + \frac{R_2}{R_1} = 1 + \frac{100000}{1000} = 101 \quad (2)$$

The microphone was plugged to the input of the amplifier through a socket which allowed to be soldered on the strip board.

The coupling was successful since the voice could be heard at the receiver. A sample of the voice recorded is shown in the Figure 6 which was taken at the output of the low pass filter of the receiver.

The signal appeared to be at the negative section of the oscilloscope screen but notice should be taken at the ground reference level which is at the right side of the Figure 6.
5. Trials

The performance of the system was good. However it was decided to try some other integrated circuits and check the performance.

The sound coming out of the speaker was not loud enough and therefore a more powerful amplifier and loudspeaker was bought. In the datasheets the LM 383, 7W Audio Power Amplifier and the TDA1015 can be seen. These in conjunction with the 12W loudspeaker (Moisture Resistant) were bought and substituted the LM380 and the miniature speaker.

The testing circuits constructed, are the ones shown in the datasheets of each device. They were constructed on a breadboard (i.e. not soldered). The performance was better, since the power coming out of the amplifier was more.

Another factor which was affecting the performance highly, was the microwave filtering. As it was estimated, the insertion loss of the filters although it was not very high, it was enough to reduce the performance. The system was tried to operate without the filters and indeed the sound coming out of the speaker was louder. However that was due to the fact that the operation was under laboratory conditions i.e. noise-free conditions. Also the oscillator output was not creating any harmonics. That ensured that only the frequency of 2.45 GHz would be transmitted. If the system had to operate in a noisy environment then the filters would be a crucial aspect.

8. Conclusions

In this paper a complete transmitting and receiving system was tested. The constructed circuit included a Voltage Controlled Oscillator (VCO), a modulator, three amplifiers, two filters and a detector at microwave frequency, an audio and power amplifier for the low frequency signal and two antenna. The carrier frequency was selected to be 2.45 GHz and the transmitted information had a bandwidth of a few kHz (voice). In order to achieve the required centre frequency, the resonators were shortened by trimming conductor material form the ends i.e. increasing the resonance frequency. The system was tested to be functional using a low frequency signal generator with an upper audio frequency of 10 kHz. The transmission of a real time analogue signal was successfully demonstrated with the use of a microphone.

References:


Vitae

Lambros Ekonomou was born on January 9, 1976 in Athens, Greece. He received a BEng (Hons) in Electrical Engineering & Electronics in 1997 and a MSc. in Advanced Control in 1998 from U.M.I.S.T. in UK. In 2006 he graduated with a Ph.D. in High Voltage Engineering from N.T.U.A. in Greece. He has worked with various companies, i.e., Hellenic Public Power Corporation S.A. and Hellenic Aerospace Industry S.A., while in 2008 he was appointed Assistant Professor in A.S.P.E.T.E.-School of Pedagogical and Technological Education.

Vassiliki Vita was born in Athens, Greece. She received a BEng degree in Electrical Engineering from the faculty of Higher School of Pedagogical & Technical Education (ASETEN/SELETE), Athens, Greece in 2000. In 2002 she received a Master of Science in Control Systems from the Department of Automatic Control & Systems Engineering, at the University of Sheffield in U.K. Since 2000 she has worked as a free-lancer engineer and since 2002 as an Electrical Engineering Lecturer.

George E. Chatzarakis was born in Serres, Greece, on May 20, 1961. He received the Dipl. Eng. and the PhD degrees in Electrical Engineering from the National Technical University of Athens (NTUA) in 1986 and 1990, respectively. Currently, he is a Professor in the School of Pedagogical and Technological Education (ASPETE) in Athens, Greece.