Chapter 1

Introduction

RF electronic designs require different techniques than electronic designs at lower frequency since:

1 The Resistors, Capacitors and Inductors used do not necessarily behave like ideal components. In particular, leads on resistors and capacitors have an inductance associated with them, which can easily dominate.

2 The wavelength of the signals is comparable to the size of components used. This presents some challenges and some opportunities.

3 The track lengths may be a significant fraction of a wavelength, allowing microstrip-lines or strip-lines, to be used as elements for filters, couplers, impedance matching circuits etc.

4 The tracks on the circuit boards must have a specified characteristic impedance, to ensure that the devices connected to it work correctly at all the required frequencies. Conventional printed circuit boards are lossy at high frequencies. Circuit boards for RF and Microwave frequencies normally use low loss materials and have carefully controlled thicknesses, to provide constant impedances for transmission lines.

At lower frequencies, many of the analogue circuits are being replaced with digital circuits. At RF frequencies, analogue circuit design techniques are the only design techniques that can be used for the design of any transmitter and receiver circuit used in Radio, TV, Microwave, Mobile Phone, Wireless LAN etc.

A typical block diagram of a receiver and a transmitter is shown in Figure 1. The basic building blocks in this diagram are: RF Transformer, Mixer, RF and IF amplifier, Local Oscillator and a demodulator or detector. In this course, we will look at many of these elements in detail.

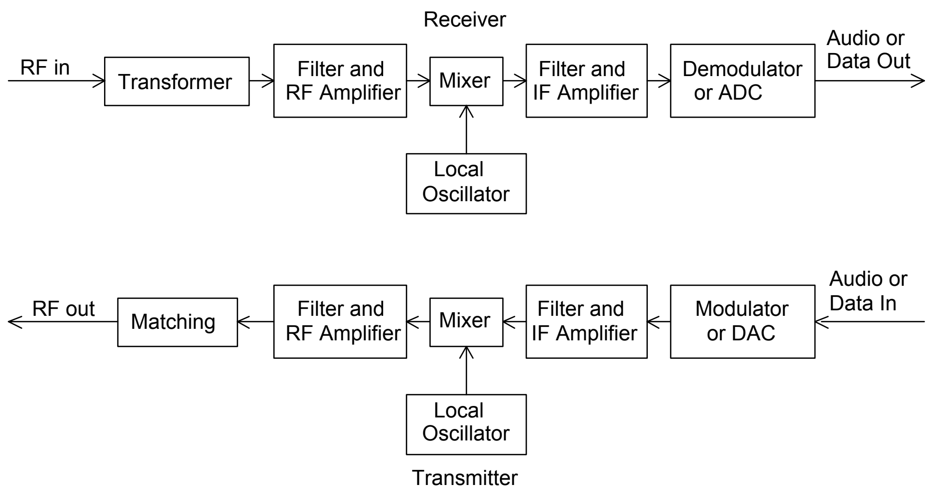

Figure 1. Typical Transmitter and Receiver Block Diagram.

For consumer devices with large production runs, such as mobile phones or USB dongles for Digital TV, Bluetooth or WLAN, many of the blocks in figure 1, are combined in one IC. A typical example of this is a Bluetooth dongle, shown in figure 2. All the RF functions, including the 2.5 GHz transmitter and receiver, all the protocol handling and the USB interface are contained in the two IC's on figure 2. The antenna is included as an element on the PCB.

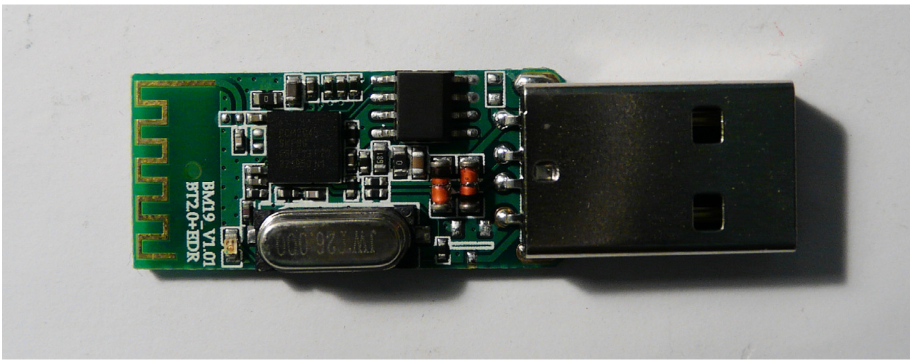

Figure 2. Typical Consumer RF Module. (Unbranded EDR Bluetooth USB Adapter)

For non-consumer applications, such IC's may be too expensive, or the performance that can be obtained from an IC cannot meet the required specifications, such as output power or adjacent carrier rejection. As a result a discrete implementation is often required for precision applications. Figure 3 shows a harmonic multiplier for a Satellite Beacon Receiver built at James Cook University. The input is a 162 MHz signal, the output is the 5th harmonic at 810 MHz. The active device is a Microwave Monolithic IC (MMIC) amplifier.

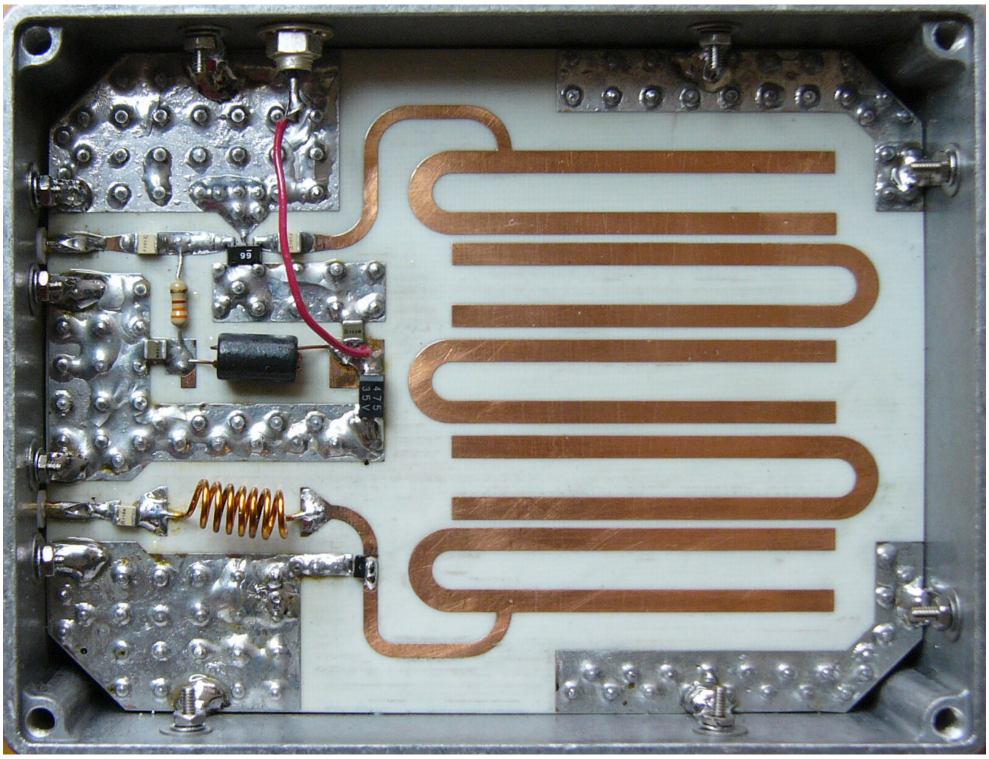

Figure 3. Harmonic Multiplier, to produce 810 MHz from 162 MHz.[1]

Currently wireless services operate at frequencies of 1.8 GHz for mobile phones, 2.5 GHz for Bluetooth and WLAN and 5 GHz for WLAN. In many cases IC's specially designed for these applications can be used at other frequencies. The designer should keep this in mind as can reduce the cost of specialised circuits.

Computer Simulation

For any commercial design, it is important to produce a properly function design as quickly as possible. Ideally there should be just one design iteration, it should be correct and reliable with the first realisation, since any further design iterations will cost more money and will delay the time before product comes to market, thus reducing any competitive advantage.

Computer simulation allows most aspects of the design to be investigated and optimised quickly before any hardware is produced. The modern computer simulation tools are very good and generally allow a correctly functioning design to be produced first time. The main commercial computer simulation systems are 1) EEsof EDA from Agilent [2] comprising Advanced System Design (ADS), GoldenGate RFIC Simulator (EMDS), Eagleware and other packages and 2) AWR software suite [3] comprising Microwave Office (MWO), Visual Systems Simulator (VSS), Analogue Office and other packages. Both perform well, and both allow linear, non-linear and time-domain circuit simulation, as well as the more detailed electromagnetic simulation. The author has used both ADS and MWO for many years and in the author's experience MWO is easier for the students to learn and as a result MWO has been used in the RF electronics course at James Cook University for which these lecture notes were produced by the author.

Both the Agilent and AWR software allow the design and simulation of RF IC's. It is very expensive to actually manufacture an RF IC. The author encourages the RF designs by the students to be manufactured, to allow the students to measure the actual performance of their designs and thus provide better feedback and a better learing experience to the students. As a result these notes concentrate on using commercial PCB substrates for components like couplers, combiners and filters and using commercial transistors and IC's in active RF designs.

References

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3. AWR Corp: MWO, VSS Design Software http://web.awrcorp.com/