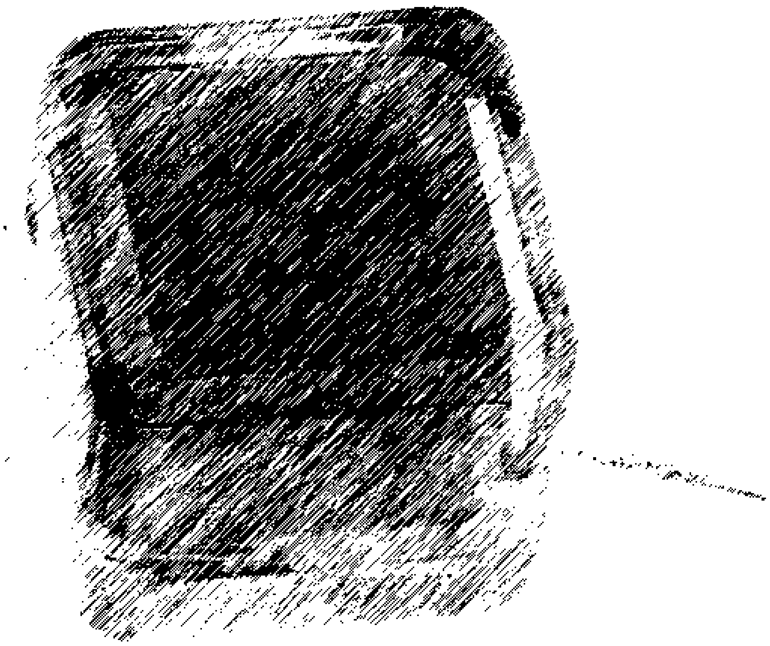
Bluetooth™ Module

Antenna Design



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Antenna Design

In any wireless communication system the antenna is a critical component whose implementation strongly influences overall system performance. This is because the antenna is the ultimately gateway between electric signals guided by signal paths on the printed circuit board (PCB) to free space transmission. If this conversion process is not implemented efficiently then degradation of system performance is inevitable.

Yet, the antenna is one of the most neglected system components in a wireless communication sytem. Quite often, though important, the antenna is put aside during the development process. It is ovious that this is a dangerous way of bringing a product to the market.

It is the objective of this chapter to demonstrate approaches for the optimum implementation of this conversion process. First, we describe the influence of the antenna on overall system performance in detail. Second, we describe a few realization of different antenna architectures and third, we draw conclusions on the integration of antenna engineers into the design process of a wireless communication process.

1 ANTENNA PARAMETERS

An antenna is characterized by a number of relevant paramters. These are resonance frequency, bandwidth, input impedance, polarization, cross polarization, antenna gain, radiation efficiency and antenna size.

1.1 RESONANCE FREQUENCY

The *resonance frequency* is the frequency where the antenna works best with respect to its intended behavior, namely the conversion of guided electric signal power into electromagnetic waves propagating through free space.

1.2 BANDWITH

The *bandwidth*, expressed in Hz, is the frequency range over which an antenna exhibits a specified behavior with respect to a relevant antenna parameter. Because there is in general more than one relevant antenna parameter, namely antenna gain, input impedance, polarization, cross polarization, radiation efficiency, the specification of bandwidth must be accompanied by the antenna parameter for which it is specified. For example, bandwidth is very often specified with respect to input impedance which then leads to bandwidth specified with respect to a certain level of return loss that is still acceptable. A typcial bandwidth specification is given as the frequency range where return loss is equal to or better than 10 dB.

1.3 INPUT IMPEDANCE

input impedance is the impedance that is experienced by a device connected to the *antenna.*

1.4 POLARIZATION

The *poarization* of an antenna in a given direction is defined as the polarization of the wave transmitted (radiated) by the antenna (Note: When not stated, the polarization is taken to be the polarization in the direction of maximum gain.). The polarization of a radiated wave is defined as that property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric field vector; specifically the figure traced as a function of time by the extremity of the vector at a fixed location in space, and the sense in which it is traced, as observed along the direction of propagation.

1.5 CROSS POLARIZATION

When describing the polarizations over the radiation sphere, or portion of it, reference lines shall be specified over the sphere, in order to measure the tilt angles of the polarization ellipses and the direction of polarization for linear polarizations. At each point on the radiation sphere the polarization is usually resolved into a pair of orthogonal polarizations, the *co-polarization* and the *cross-polarization*. To accomplish this, the co-polarization must be specified at each point on the radiation sphere.

1.6 AXIAL RATIO

In general the time-harmonic wave is elliptically polarized (i.e. the tip of the electric field vector traces an elliptical locus in space. The *axial ratio* is defined as the ratio of the major axis to the minor axis of this ellipse.

1.7 LHCP

LHCP (Left Hand Circular Polarization) is a circular polarization (i.e. the curved traced by the end point of the arrow representing the instantaneous electric field), which has a counterclockwise rotation along the direction of propagation.

1.8 RHCP

RHCP (Right Hand Circular Polarization) is a circular polarization (i.e. the curved traced by the end point of the arrow representing the instantaneous electric field), which has a clockwise rotation along the direction of propagation.

1.9 ANTENNA DIRECTIVITY

The *directivity* of an antenna is defined as the ratio of the radiated power per unit spatial angle (intensity), in a given direction, to the intensity that would be obtained if the power fed to the antenna were radiated isotropically (isotropic spheric radiator). The radiation intensity corresponding to the isotropically radiating antenna is equal to the power accepted devided by 4 π. Gain is usually expressed in dB.

1.10 ANTENNA GAIN

The *antenna gain* is defined as the antenna directivity multiplied by the radiation efficiency. Antenna gain is important for the estimation of system performance parameters related to transmission and reception of power (link budget estimations).

1.11 RADIATION EFFICIENCY

The *radiation efficiency* is defined as the ratio of the power that is radiated by an antenna to the power that is accepted by the antenna. The power accepted by the antenne is equal to the total power fed to the antenna through signal lines minus the power that is reflected by the antenne due to impedance mismatch.

1.12 ANTENNA SIZE

In general the geometrical size of an antenne is alway related to the wavelength of the signal that the antenna must transmit or receive. Typically, the relevant characteristic size of an antenna is half the wavelength of the signal. For example, the BluetoothTM signal has a frequency of roughly 2.440 in the middle of the band. The corresponding wavelength in air is therefore 123 mm. Half the wavelength is then 61.5 mm. Because the wavelenght of a signal is reduced in an antenna system by a factor which is the square root of the respective dielectric antenna material, the half wavelength is about 30 mm.

While there are techniques to further reduce antenna size below this half wavelength limit, such techniques always bring a tradeoff for the relevant antenna parameters with them. For example when considerably reducing the size, antenna bandwidth, gain and radiation efficiency will be greatly reduced.

Therefore, it is generally not recommended to design ultra-small antennas because system performance directly depends on antenna gain. Ultra-small antennas in general have very low gain.

The aqbt3232 and aqbt3030 developed by antenna design – Dr. Benedikt Oswald represent a well balanced tradeoff between performance parameters, geometrical antenna size and cost issues.

2 INFLUENCE OF THE ANTENNA ON OVERALL SYSTEM PERFORMANCE

The antenna is the system element that converts electric signals guided by traces on the printed circuit board into signals propagating through free space. Therefore, the antenna acts as an impedance and mode conversion device. The antenna is the ultimate air interface whose performance is critical with respect to overall system performance.

A number of factors which influence overall antenna performance should be considered for optimum transceiver operation:

A) Power reflected back to the source: if the antenna is not matched to the system, a considerable fraction of the electric signal power is not radiated into free space but reflected back to the source. Therefore, considerable power is wasted. In such a situation the conversion efficiency of the antenna is low. The electric power that is not radiated is dissipated inside the system into ohmic heat. This is particularly disastrous in communication systems that rely on rechargeable batteries for power supply. Low antenna efficiency therefore leads to reduced device operation time and ultimately to reduced user acceptance because the batteries must be recharged more often and the advantage of wireless communication is not fully used.

B) Interaction of the antenna with its environment and Pattern: short range wireless communication, such as Bluetooth™, used in office and other environments populated with bulky furniture, in general can not communicate between each through line of sight. But rather, communication links are established by radio waves that experience reflection and refraction until they reach their partnering device. There may even be different versions of the same originating signal that arrive at the targeted device, delayed in time due to to differing geometrical lengths of their propagation paths. This type of propagation environment is also called a multipath environment.

In particular, because the location and orientation of the antenna of the receiving device is not a priori known, the antenna of the transmitting device must not be directive, i.e. it must not prefer certain directions of transmission over others. In contrary, antennas used in this type of communication system should transmit equally in all spatial directions. Although this is physically not feasible, real implementations should keep this in mind.

3 WHERE SCHOULD ANTENNAS BE LOCATED ?

Printed circuit boards (PCB) are in general a source of signal noise, mainly resulting from harmonics and subharmonics resulting from digital clock. Since microsprocessor speeds are in excess of 1 GHz, CPU generated lower harmonics must be considered as noise sources. In particular radiation power levels specified in FCC Part 15 for non-intentional radiating devices are, such as PC's, are much higher than the minimum signal levels of Bluetooth™ circuitry. Therefore, the location of the antenna must not be only be chosen with respect to radiation pattern in mind but the antenna placement must be chosen so that first the antenna does not disturb other parts of the system and second that no disturbances to the Bluetooth™ system are caught through the antenna.

4 WHEN SHOULD THE ANTENNA BE CONSIDERED DURING SYSTEM DESIGN ?

Due to its impact on overall system performance, the antenna should be considered in system design right from the start. Today, miniaturization and industrial design of mobile and wireless communication sytem are of primary importance. Nevertheless, the technical performance of the antenna does not tolerate any compromises. Because today, antennas can be designed for almost any type of three-dimensional shape, it is therefore essential that the antenna engineer is integrated into the design process as early as possible. Given, the ideas of research & development engineers and industrial designers he can then explore the space of available solutions and chose the ones that ultimately fit into the various design constraints that are always present in the development process.

5 PHYSICAL BASES AND LIMITS

Antennas are devices that can not be arbitrarily shrunk in size without compromising with respect to antenna performance parameters. For example, the geometrical size of an antenn can be reduced, but only at the cost of antenna gain, efficiency and bandwidth.

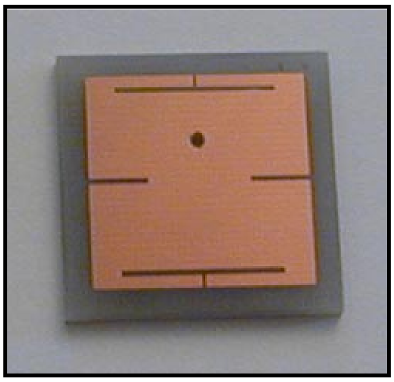
While browsing through the product sheets of antenna companies it might appear that antennas can be made arbitrarily small without any compromise with respect to antenna gain, bandwidth and effieciency. This is unfortunately not true. While it is possible to make the **radiating element** of an antenna quite small, in units of free-space wavelength, antenna manufacturers have a certain tendency not to mention that such a radiating device also needs a ground plane in order to obtain the antenna gain specified in the antenna's data sheet and sometimes also to be properly matched.

Therefore, when reading about about the 'ultra-miniaturized antenna xy', always ask for the size of the ground plane required for proper antenna gain and impedance matching. Often, the answer leads to the insight that the antenna is not that small as suggested in the datsheet...simplly because antennas are physical representations of mother nature's constraints.

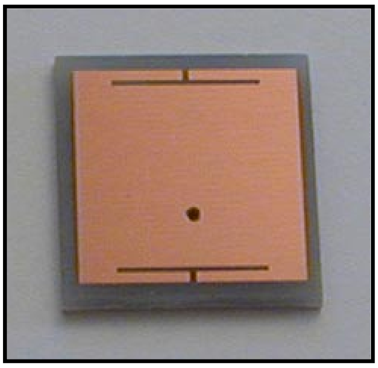
Additionally, there are statements such as 'our antenna is completely independent on ground plane size and environment'. While it might be true that one antenna type is less susceptible to ground plane size or the structure of its environment than the other, be assured that an antenna *always* interacts with its environment because this is the essence of any antenna's reason of existence: convert guided electric signals into signals that propagate through free space.

6 TYPES OF ANTENNAS

6.1 MICROSTRIP PATCH ANTENNA (MPA)



Where low profile and low weight are important microstrip patch antennas, such as the model aqbt3030, shown just below, supplied by the Swiss company antenna design - Dr. Benedikt Oswald are the antennas of choice. Microstrip patch antennas use a metallic patch of specifica shape to form a structure which acts as a leaky resonator. The microstrip patch antenna **aqbt3030** (left) and the microstrip patch antenna **aqbt3232** (right) have been designed on the basis of the standard PCB material FR4 which makes them both cost effective and ready for mass production.



6.2 DIELECTRIC RESONATOR ANTENNA (DRA)

While microstrip patch antennas are attractive candidates for the operation of Bluetooth™ transsceivers, they also have a few drawbacks. One of the more important is their releatively low bandwidth and low efficiency, if standard PCB materials are used. The true bandwith and efficiency answer to this problem is the dielectric resonator antenna (DRA). Shown on the right, is the model **aqdra2401** from the Swiss company *antenna design - Dr. Benedikt Oswald* which is a ruggedized, cube shaped DRA with high gain, high radiation efficiency and considerable bandwidth for optimum operation of Bluetooth™ transceivers. The aqdra2401 is connected to the Bluetooth™ module with a standard coaxial cables and can be placed in the vicinity of the Bluetooth™ module for optimum operation.

6.3 PCB BOARD TRACE ANTENNA

Depending on the complexity of the PCB layout and the signal speeds on the board it might also be possible to integrate an antenna directly into the PCB design. Such a solution can be very interesting with respect to cost and fabrication issues but it requires a careful design and investigation of possible side effects onto other parts of the complete system. Electromagnetic compatibility issues should be carefully explored if this antenna architecture is chose.

7 CONCLUSIONS

Because the antenna is the ultimate air interface its implementation critically influences overall system performance. Therefore, in order to avoid costly redesigns or even aborted development projects, it is essential that the antenna is fully considered as a critical system component. It is therefore essential that during the integration of wireless communication capability, such as Bluetooth^{TM} engineers participate in the system design process as early as possible, probably

Because every system and device development process has its own set of specific design goals and constraints, it is almost never possible to use standard off-the shelf antenna components because the antenna is a device that interacts with its environment in a complex way. Rather, a base antenna design is considered and adapted for a specific task. This adaptation process requires rapid turnaround time because the rest of the design team proces can not wait for the antenna design to complete. This can only be solved through the deployment of state of the are electromagnetic CAD solvers which is the expertise of the innovative Swiss company *antenna design - Dr. Benedikt Oswald.* The company has many years of experience in antenna design, including a track record of its founders that spans antennas from 1.575 GHz (GPS) up to 77 GHz (antennas for automitive collision avoidance radars)

More important, the company relies on its exensive know how of using state of the are electromagnetic CAD tools. The usage of those design tools makes it possible to reduce antenna adaptation and integration times from months to a few days or even hours, depending on the complexity of the project.

Starting from our standard antenna designs we are able to adapt these base designs to your system requirements and integrate them for optimum performance in time spans that do not stress your development budget but relieve it from unnecessary financial burden.