National Semiconductor

Applications Note
5th August 2003
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Revision 0.2

Cordless Voice Module Antenna : Application Note

General Description

This Application Note describes some of the antennas and basics on design that can be used with the Cordless Voice Module. PIFA antennas are explained along with information on their design and matching to the CVM output. Diversity antennas are strongly recommended for the CVM module as they offer far better reception quality and the principle of diversity is described.

Revision History

Revision 0.1 — 12th February, 2003
Revision 0.2 — 5th August, 2003

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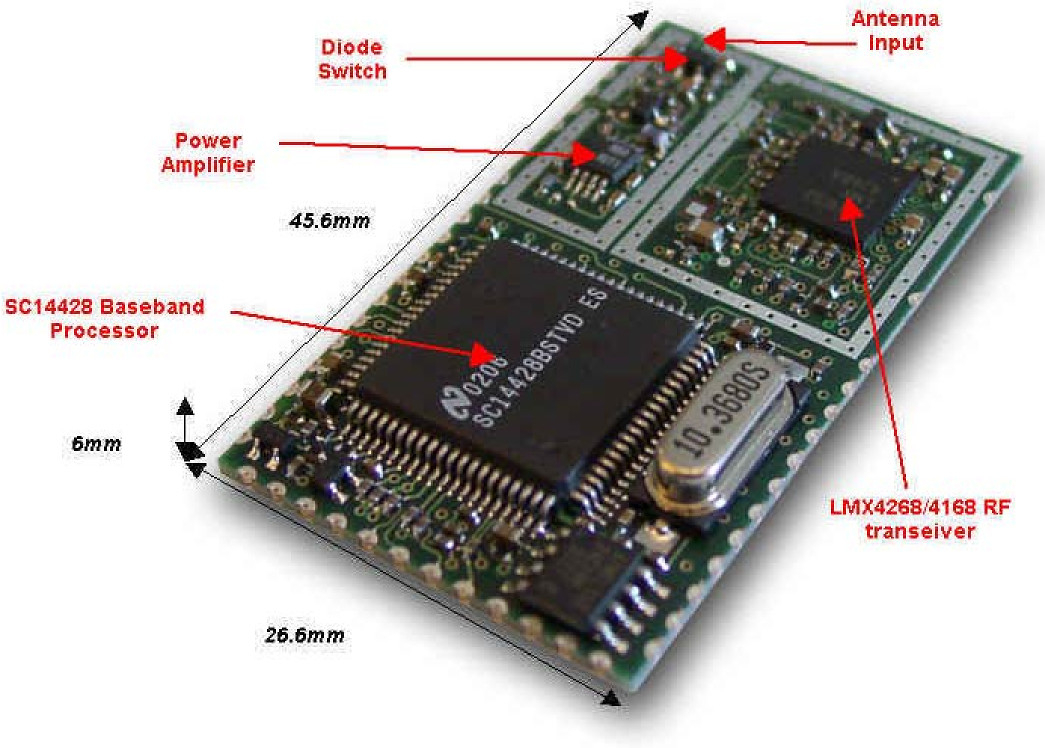
Acronyms

EMC	Electro-Magnetic Compatibility
DCT	Digital Cordless Telephony
DECT	Digital Enhanced Cordless Telephony
PCB	Printed Circuit Board
GSM	Global System for Mobile communications
VSWR	Voltage Standing Wave Ratio
PIFA	Printed Inverted F Antenna
BER	Bit Error Rate
CVM	Cordless Voice Module
RSSI	Receiver Signal Strength Indicator
RF	Radio Frequency
TEM	Transverse Electro-Magnetic
λg	Wavelength of micro-strip guided wave

Module Description



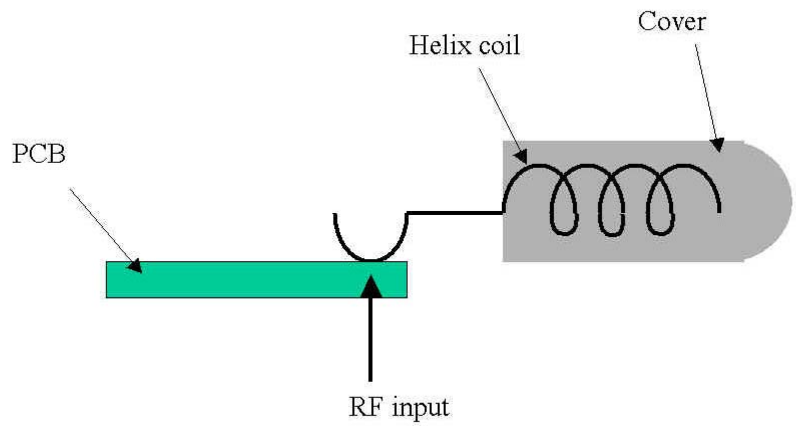
The CVM module consists of an SC14428 baseband processor, LMX4168 1.9GHz or LMX4268 2.4GHz RF transceiver, crystal oscillator, power amplifier and diode switch as shown above. The dimensions of the module are 26.6mm $\times$ 45.6mm and the transceiver plus power amplifier sections would be shielded from to meet EMC requirements. The module as a whole is designed to be mounted on a motherboard that will also contain the antenna. Different types of antennas can be used based on size and performance and a few will be discussed in this report. This report will discuss the basics of such antennas that are vital to any designer wishing to implement into their application.

Types of Antennas

1.9 and 2.4GHz antennas that can be used for DECT and DCT respectively are available in several different designs, all suitable for mobile application such as printed line, inverted F, dielectric chip surface mount and stub helix. Manufacturers that produce such antennas include Allgon, GigaAnt, Yokowo, Mitsubishi, Rangestar and several others that will also make custom designs if the volumes are large enough.

Stub Helix

This type of antenna is most commonly used for GSM mobile phones, but tuned to 1.9 and 2.4GHz, it has excellent RF performance in terms of bandwidth and efficiency of radiation and has only one connection point to the main PCB. It does not require a ground connection or a ground plane and because of its large bandwidth it will not easily be de-tuned by user handling. But like all the antennas mentioned in this report, it does need tuning to the individual mechanics of the application in which it is being used. Different shapes and materials used for the chassis will distort the radiation pattern and pull the center frequency of the antenna. This is one disadvantage of helix antennas, because they are more difficult to tune than a printed antenna where the resonant length can be easily changed.



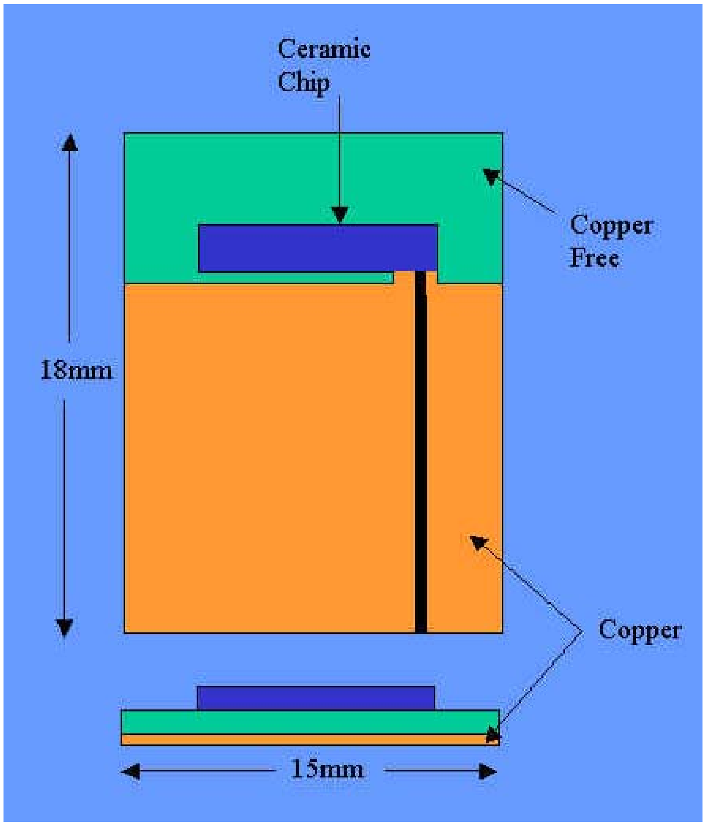
The negative point of course with this type of antenna is that its not low profile, it projects from the side of the PCB. For this reason they are often not used for mobile applications.

Surface Mount Dielectric Chip

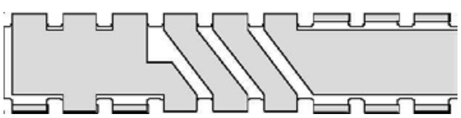
A low profile, smaller, lighter and cheaper antenna is the dielectric chip antenna, this consists of a high dk dielectric slab with the active element printed on top. The reason for using a dielectric slab rather than printing the element on the PCB directly is that it is smaller due to the concentrated electric field within the dielectric material. This type of antenna is low profile and can be machine mounted during assembly, but it does not yield as good performance as the stub helix. Being small means narrow bandwidth, worse efficiency and easily de-tuned through handling.
Even though the antenna element is quite small (approx. 12×2mm) the size of the whole antenna is much larger because of the ground plane required for the antenna to function correctly. In addition to this, a certain copper free clearance needs to be maintained around the radiating element both in a horizontal plane as shown in the diagram and some clearance in the vertical plane. The results of making the ground plane or copper free area too small will be reduced bandwidth and as a rule of thumb, the antenna should have a bandwidth which covers the entire DECT or DCT band with VSWR<2.5.

Typical Requirement Specifications;

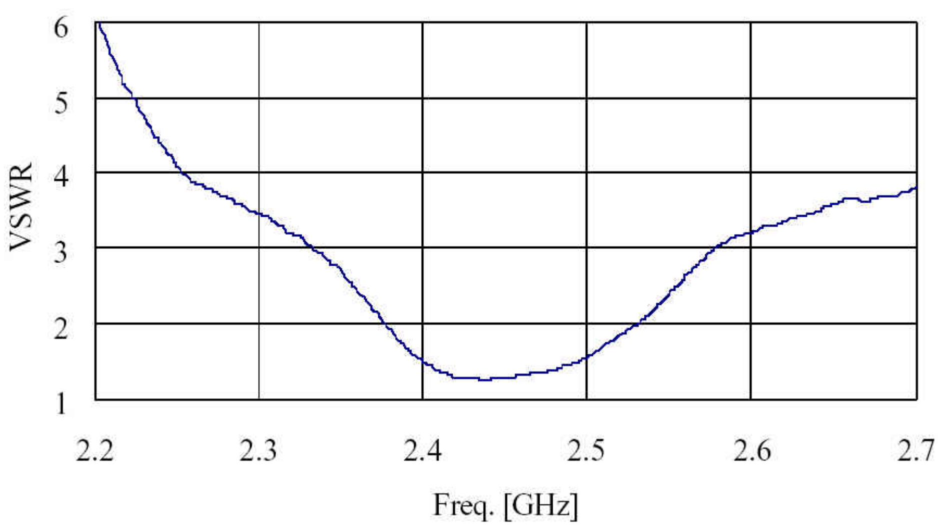
- **Bandwidth** – As mentioned this should cover the entire band with VSWR<2.5, however, small bandwidth antenna will be prone to de-tuning effects hence the bandwidth should ideally be larger than this (see graph below). If the required bandwidth cannot be achieved then either the antenna ground area and/or the radiating element is too small. A matching network maybe also be required in addition, this should be placed as close as possible to the antenna input.
- **Radiation Efficiency** – Anything greater than 70% would be considered good. Small mobile antennas will certainly have worse efficiency than larger $\lambda g/2$ or full λg antennas.
- **Radiation Pattern** – Should be omni directional for mobile applications. But the pattern of small antennas ($L<<\lambda g$) is difficult to control and may have an erratic shape, but this is not a serious issue.



2.4GHz antenna

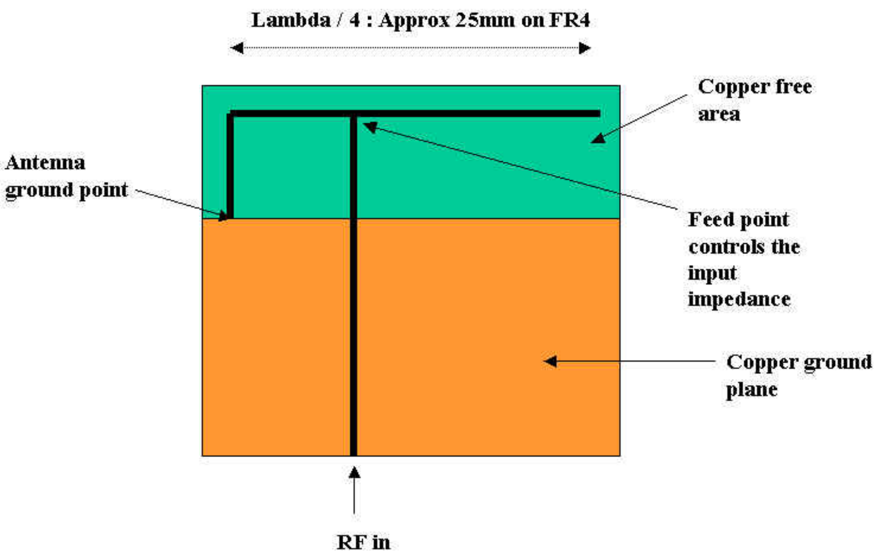


Radiating element (chip).



VSWR into antenna port.

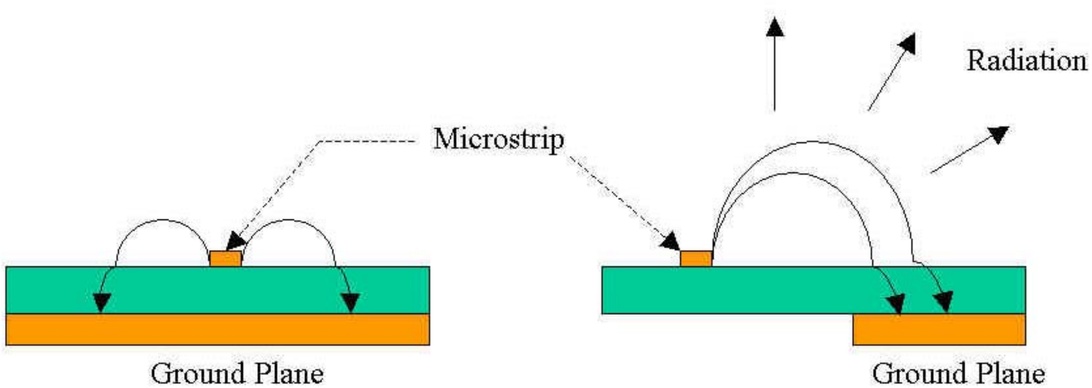
Printed Inverted F (PIFA)



A PIFA antenna is shown above. The main radiating element is λg/4 in this case, or it could be half or full λ for better RF performance. The back of the element is grounded with through via's placed close to the grounding point to give a good RF ground, this is to provide a node where the electric field is close to zero. The radiating element being quarter wavelength will produce an anti-node on its other end where the electric field is strongest, hence this end of the element will become the active radiating region of the antenna. An area of ground plane and copper clearance is again required to give the antenna its required bandwidth. The antenna element is approximately 25mm long since it is printed on FR4, this is considerably larger than the dielectric chip, but of course this kind of antenna will be cheaper to manufacture than the dielectric chip at the expense of size. The position of the feed point along the element will control its input impedance to a certain extent and can be used as a tool for matching along with the antenna dimensions and a discrete matching network.

Principle of Surface Mount, Printed or Patch Antennas

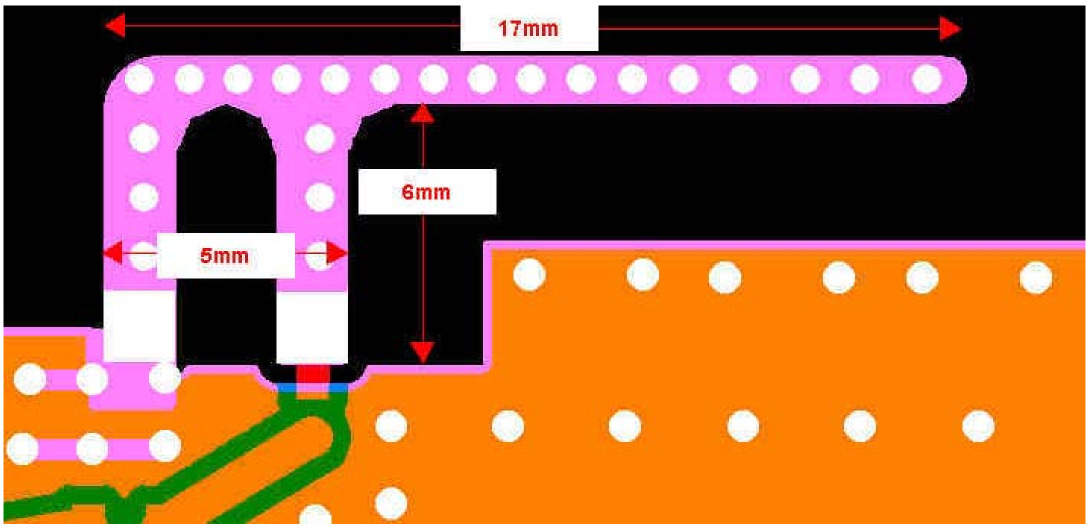
All such antennas work on a similar principle, radiating element, clearance around the element (top and bottom) plus a ground plane on one side. It is necessary to create a fringing E-field with a large arc to give rise to radiation emission, else the field will be contained and non-radiating.



Consider a micro-strip line as shown above and the electric field lines that run from it through the dielectric substrate to ground. Although micro-strips do radiate a little, they are not good antennas by themselves. In order to turn them into good radiators it is necessary to move the ground plane from under the strip-line, hence forcing the electric field to arc over a greater distance, and it is this arcing field that produces the radiation. If the ground plane is moved too far, then the electric field would cease altogether, therefore there is a critical distance.

Reference Design: Example

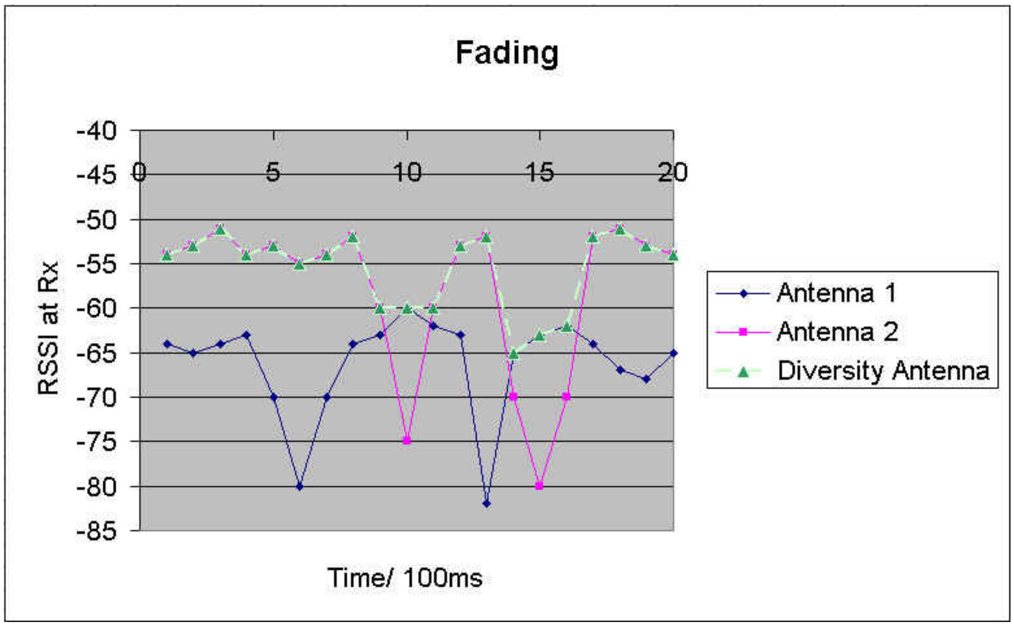
The physical dimensions of the antenna are predominantly governed by three factors, the frequency of resonance, the dielectric constant of the substrate on which the antenna element is printed and the thickness of the substrate. High frequency obviously means smaller dimensions, also high dielectric constant and thick substrate means the field lines are more densely packed, which means smaller physical size.
In this example for the CVM module (at 2.45GHz center frequency) the relative dielectric constant is 4.3 and the thickness of the substrate is 1mm.



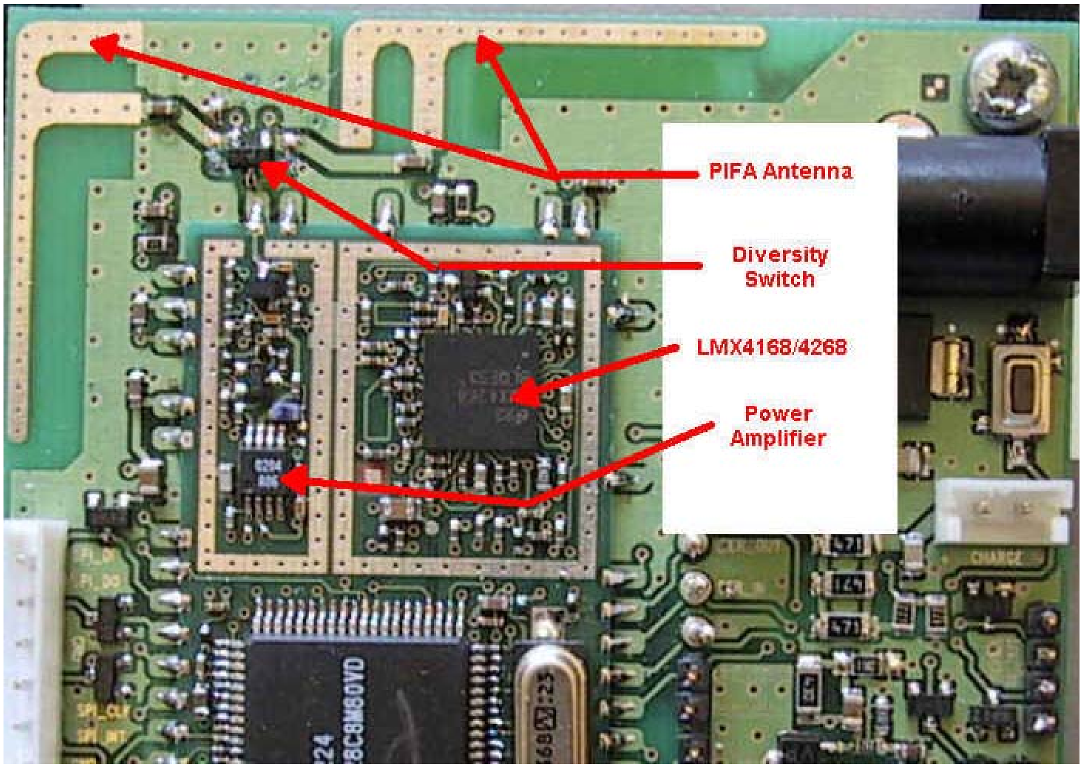
In this case the maximum dimension of the antenna is 17mm, $\lambda g/4$. The antenna could also be 34 or 68mm long, $\lambda g/2$ and full λg respectively, depending on space available. The advantage of making it larger is greater bandwidth and immunity to de-tuning.

Diversity Recommendation for CVM

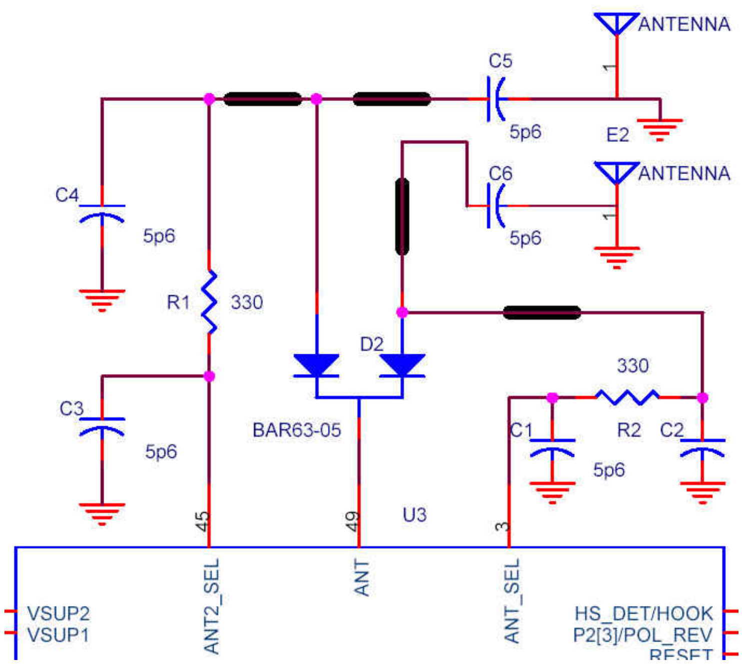
In mobile applications, the DECT/DCT handset is constantly in a state of motion, this results in fading and Doppler. Fading is when radiation reflected from multiple surfaces is combined at the receiving antenna either constructively or destructively interfere giving a rapidly varying signal level at the receiver input. Doppler is when the frequency of the carrier is shifted slightly during fast movement away from or towards the receiver, because the TEM wave is compressed or stretched. The effect of both and particularly fading is reception difficulty and increased BER, in extreme conditions or when the signal level is weak, the link maybe dropped altogether.
One method to compensate this is through the use of diversity, which consists of two antennas placed at least 15 to 20mm apart and/or perpendicular to each other The two antennas are connected to the receiver by means of a pin diode switch and are monitored for signal level at the start of each burst, the antenna with the highest level is then selected for data reception.



We see from this example that when the RSSI level of antenna 2 drops lower than antenna 1, the switch is made to the higher RSSI. Hence the diversity arrangement prevents the signal from dropping too low during a fade since it is very unlikely that both antennas will go though a null at the same time, since they are separated slightly and are arrange perpendicularly.
Although the diversity arrangement is recommended for the CVM module, it comes at the expense of having two antennas and greater use of PCB real estate.



The RSSI in this case is measured during pre-amble and logic signals from the baseband is applied to the pin-diode switch which causes it to switch to either antenna depending on the highest RSSI measured. The data burst can then be received with the best signal quality.



Ant_sel and Ant2_sel are the logic signals that bias the diode pair D2 to conducting or non-conducting states, hence select the appropriate antenna.

Summary

Three types of antennas have been considered for use with the CVM module;

Type of Antenna	Performance	Profile	Cost	Physical Size
Stub Helix	Good bandwidth and efficiency, does not require matching network.	High: Projects from the side of the PCB	High	2.4GHz antenna is approximately 15mm long, but projects, does not need ground plane to function
Surface mount ceramic chip	Reasonable performance on $\lambda g/4$. Small bandwidth and reduced efficiency, can become de-tuned during handling	Low: Can be machine mounted during assembly, no more than 0.5mm thick	Medium	Element for 2.4GHz is approximately 12mm long, but needs ground area and clearance around active region
Printed Inverted F	Reasonable performance on $\lambda g/4$. Small bandwidth and reduced efficiency, can become de-tuned during handling	Lowest: Printed on PCB	Low	Element for 2.4GHz is approximately 25mm long, but needs ground area and clearance around active region

In mobile applications, diversity is recommended to give good signal level at all times and avoid fading nulls that can corrupt or drop the link altogether. Any of the above antennas mentioned can be used for diversity as long as they are placed at least 15 to 20mm apart and/or perpendicular to each other.

Points for Consideration

- Surface mount chips or PIFA antennas require ground plane and clearance around the radiating element.
- Larger antennas, ie/ full λ for half λ will have better efficiency and bandwidth than smaller antennas.
- Small antennas are prone to de-tuning due to their narrow bandwidths. Certain volume clearance should be maintained around the active element.
- Even plastic chassis can cause de-tuning and loss of radiated power if it comes too close to the active element.
- The resonant length of the antenna will be affected by the shape and size of the chassis and also the material that it is composed of. The antenna therefore needs to be designed with the application for which it is being used.
- Handset antennas will almost certainly be de-tuned when handling, amount of de-tuning is dependent on the distance of the hand and head to the active part of the antenna.
- Chassis around the antenna should not be metalised in any way.
- 3 or 5 element matching network can be used to increase the bandwidth into the antenna or match to the strip-line.

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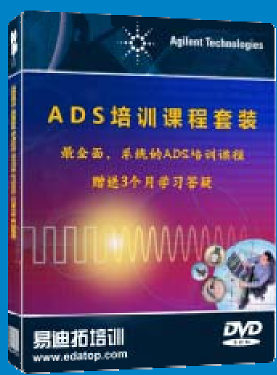

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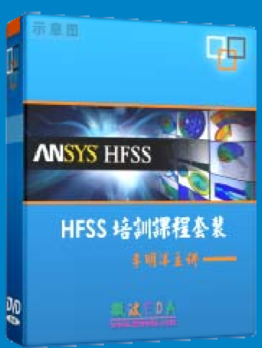

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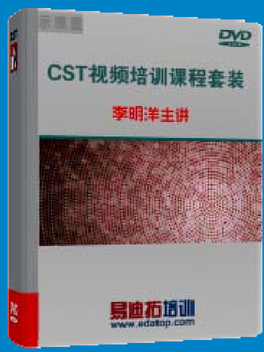

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