LINX TECHNOLOGIES
WIRELESS MADE SIMPLE

HIGH-PERFORMANCE
# ES SERIES
RF TRANSMITTER

ES TRANSMITTER MODULE DESIGN GUIDE

DESCRIPTION:

Housed in a tiny SMD package, the ES Series offers an unmatched combination of features, performance and cost-effectiveness. The ES utilizes an advanced FM/FSK-based synthesized architecture to provide superior performance and noise immunity when compared to AM/OOK solutions. An outstanding 56Kbps maximum data rate and wide-range analog capability make the ES Series equally at home with digital data or analog sources such as audio. A host of useful features including PDN, LVLADJ, low voltage detect, and a microprocessor clock source are provided. ES-Series components will be available in a wide range of frequencies to take full advantage of worldwide applications. The first model operates at 916.48MHz, which in North America allows an unlimited variety of applications including data links, audio links, process and status control, home and industrial automation, security, remote control/command, and monitoring. Like all Linx modules, the ES Series requires no tuning or external RF components (except an antenna).

0.630"

0.510"

0.125"
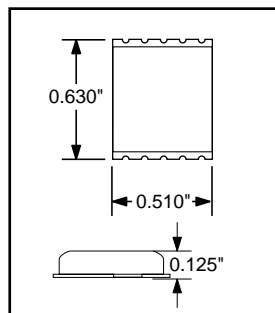
PHYSICAL DIMENSIONS

FEATURES

- Ultra-compact SMD package
- FM/FSK modulation for outstanding performance/noise immunity
- Precision-frequency synthesized architecture
- Very low current for long life in battery-powered applications
- Direct interface to analog and digital sources
- High data rate - 56,000 bps max.
- Wide-range analog capability including audio 20Hz-28KHz
- No tuning or external RF components required (except antenna)
- User powerdown input
- Low-voltage detect and microprocessor clock output
- Outstanding cost-to-performance ratio

APPLICATIONS

- Wireless Data Transfer
- Wireless Analog/Audio
- Home/Industrial Automation
- Keyless Entry
- Remote Control
- Fire/Security Alarms
- Wireless Networks
- Remote Status Sensing
- Telemetry
- Long-Range RFID
- RS-232/485 Data Links
- MIDI Links
- Voice/Music Links/Intercoms

ORDERING INFORMATION

PART #	DESCRIPTION
TXM-***-ES	ES-Series Transmitter
RXM-***-ES	ES-Series Receiver
EVAL-***-ES	ES Basic Evaluation System
MDEV-***-ES	ES Master Development System
***= 916.48 (Additional Frequencies TBA)	

*ABOUT THESE MEASUREMENTS

The performance parameters listed below are based on module operation at 25°C from a 3VDC supply unless otherwise noted.

Parameter	Designation	Min	Typ	Max	Units	Notes
POWER SUPPLY						
Operating Voltage	VCC (pin 3)	2.1	3	4	VDC	
Current Consumption	Icc	6.5	7	7.5	mA	
Sleep Mode			90		uA	7
ENVIRONMENTAL						
Operational Temp.		0		70	°C	7
TRANSMIT SECTION						
Center Frequency	Fc		SEE TABLE 1		MHz	
Fc Tolerance		-50		+50	KHz	1
Output Power	Po	-3	0	+4	dBm	2,3
Output-Power Control Range			65		dB	2,4,7
Harmonic Emissions	Ph		-55	-47	dBc	2
Spurious Emissions	compatible with FCC part 15					
Frequency Deviation		90	110	130	KHz	5
FSK Data Rate		200		56,000	Bps	7
Required Transition Interval				5	ms	7,11
Modulation Voltage						
Digital (Mark)		3	5	5.2	VDC	8
Digital (Space)		0	0		VDC	
Analog		0		5	Vp-p	9
FM Analog Bandwidth		.02		28	KHz	6,7
ANTENNA PORT						
Designed for match			50		ohms	7
TIMING						
Power-on to Valid Transmit		.1	.5	1.5	ms	7,10

NOTES:
1) Center frequency measured while modulated with a 0-5V square wave.
2) Into a 50-ohm load.
3) LVLADJ open.
4) Maximum power when LVLADJ open, minimum power when LVLADJ grounded.
5) TXDATA pin modulated with a 0-5V square wave.
6) The audio bandwidth is wide to accommodate the needs of the data slicer.
7) These parameters are only characterized and not tested.
8) The ES is optimized for both 0-5V and 0-3V modulation when sending digital data.
9) Analog signals including audio should be AC-coupled.
10) Time to transmitter readiness from the application of power to VIN or PDN going high.
11) Maximum time without a data transition.

MODEL	Center Frequency		UNITS
	TX	RX LO	
TXM-433-ES	Not Released		MHz
TXM-868-ES	Not Released		MHz
TXM-903-ES	Not Released		MHz
TXM-916-ES	916.48	905.78	MHz
TXM-921-ES	Not Released		MHz

Table 1
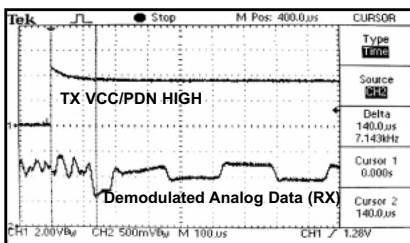
TYPICAL PERFORMANCE GRAPHS
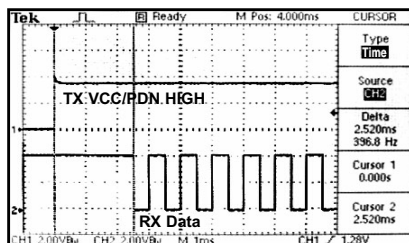

Figure 1: TX Powerup to Valid RX Analog

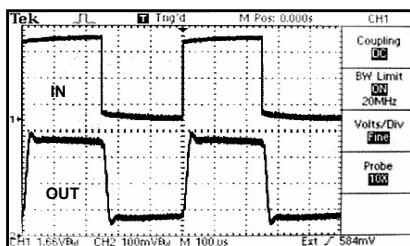*Figure 2: TX Powerup to Valid RX Data*

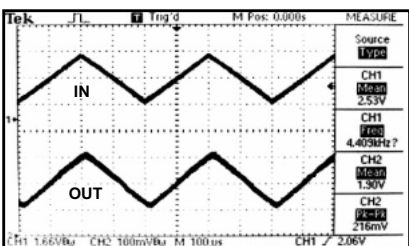*Figure 3: Square-Wave Modulation Linearity*

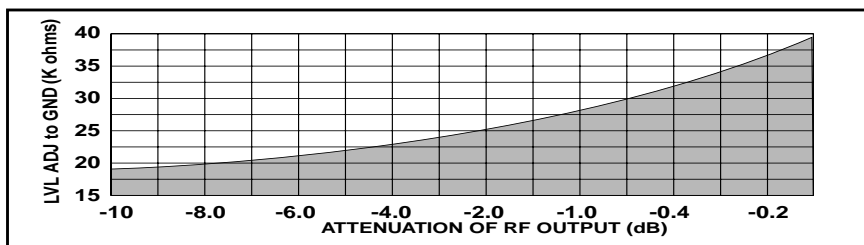*Figure 4: Triangle-Wave Modulation Linearity*

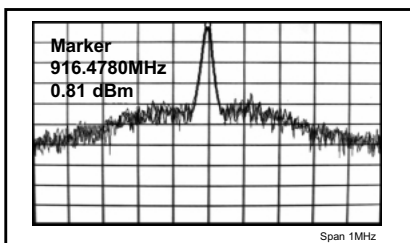
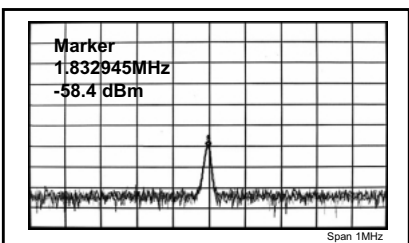*Figure 5: Level Adjust Attenuation Chart*

Figure 6: TX Carrier

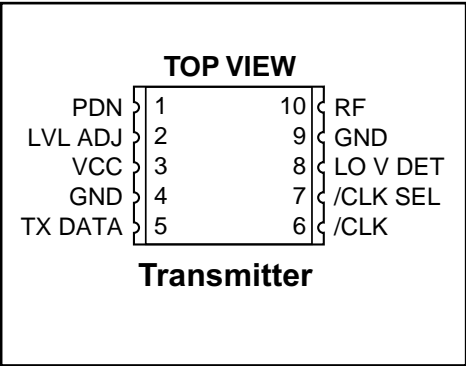*Figure 7: 2nd Harmonic*

PIN DESCRIPTION

Figure 8: ES-Series TX Pinouts
(viewed looking down on top cover)
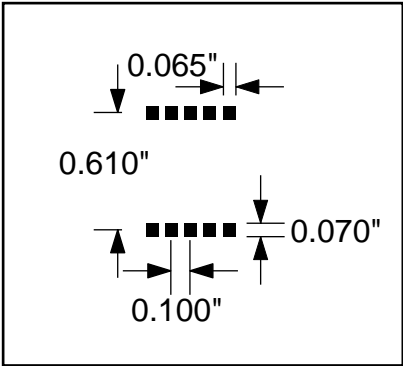
Figure 9: Recommended TX Pad Layout

PIN#	Pin Title	Description
1	PDN	Logic Low Powers Down the Transmitter
2	LVLADJ	Open for Maximum TX Power - Insert Resistor to GND to Reduce by up to 65dB
3	VCC	2.1-4VDC Supply
4, 9	GND	Module Grounds Tie to Common Groundplane
5	TXDATA	Analog or Digital Content Input to be Transmitted
6	/CLK	Divided Clock Output
7	/CLK SEL	Logic Low Selects Divide by 256 Logic High Selects Divide by 1024
8	LO V DET	Low Voltage Detect Output Goes Low When Vcc <2.15VDC
10	RF/ANT	50Ω Antenna Port

Figure 10: ES-Series Block Diagram

INTRODUCTION

The TXM-xxx-ES module is a single-channel transmitter designed for the wireless transfer of digital or analog information over distances of <1000 feet outside and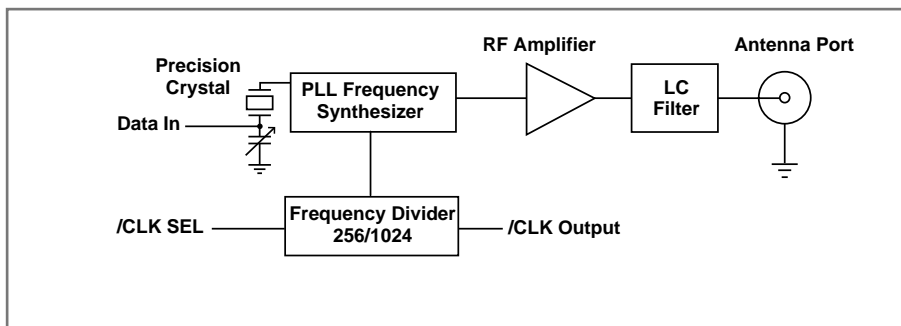 <500 feet inside.The TXM-xxx-ES is based on high-performance synthesized architecture. FM/FSK modulation is utilized to provide superior performance and noise immunity over AM-based solutions. The ES Series is incredibly compact and cost-effective when compared with other FM/FSK devices. Best of all, it is packed with many useful features and capabilities which offer maximum application flexibility to the designer. Some of these features which will be discussed in depth in this design guide are:

/CLK Output (use for external micro-controller)

LO V DET   (low-voltage detection)

LVLADJ   (adjust RF output power)

THEORY OF OPERATION

The ES FM/FSK transmitter is capable of generating 1mW of output power into a 50-ohm load while maintaining harmonics and spurious emissions within legal limits. The transmitter is comprised of a VCO and a crystal-controlled frequency synthesizer. The frequency synthesizer, referenced to a precision crystal, locks the VCO to achieve a high-Q, low phase-noise oscillator.

The transmitter modulates the carrier with the baseband signal present at the TXDATA pin. If the signal is analog in nature, it will FM modulate the carrier. If the signal is digital, the modulation method becomes FSK. Modulation is achieved by direct modulation of the reference crystal. By modulating the transmitter in this manner, a wide modulation bandwidth is achieved. If the transmitter LO were modulated, the frequency synthesizer would track out modulation within the bandwidth of the loop filter (this is a common limitation of most synthesized FM transmitters).

No external components (excluding an antenna) are required. Linx offers a wide selection of antennas designed for use with the ES transmitter module.

APPLICATION OVERVIEW

Like all Linx modules, the ES Series is designed for ease of application even by inexperienced users. It must be recognized, however, that all wireless links differ from hardwired applications in several key ways. The most obvious are perhaps timing and interference, but there are other critical areas which are important to consider as well. These include:

• Transparency • Interference • Timing
• Board Layout • Antenna Selection • Legal Compliancy

MODULE TRANSPARENCY

It is important to note that the ES-Series components do not encode or packetize the signal content in any manner. Naturally, the transmitted signal will be affected by such factors as noise, edge jitter, and interference but the transmitter does not purposefully manipulate or alter the original signal. This transparency eliminates the issues of variable latency common to traditional radio modems and gives the designer tremendous flexibility in the structure of signals or protocol. A drawback to this approach is that the performance and reliability of the link are in part determined by external factors such as the quality of software and hardware.

INTERFERENCE CONSIDERATIONS

It must be recognized that many bands, including those used by the ES Series, are widely used and the potential for conflict with other unwanted sources of RF is very real. Despite careful design, all RF products are at risk from the effects of interference. It is important that the types and manifestations of interference are understood and taken into account. For a full discussion of this important issue please refer to the ES-Receiver design guide.

TIMING CONSIDERATIONS

There are two general areas of timing that are important to consider when designing with the transmitter. The actual time value for each is listed under the "Performance Specifications" section of this document.

1. Start-up time

Start-up time is the time to transmitter readiness from the application of power to the VIN pin or the PDN pin going high.

Transmitter readiness is defined as the presence of a fully locked carrier.

2. Required transition interval

This is the maximum amount of time that can elapse without a transition on the TX data pin.

It is always important to think of data in both the analog and the digital domain. Because the data stream is asynchronous and no particular format is imposed, it is possible for the data to meet the baud-rate requirements of the module from a digital standpoint and yet violate the analog frequency parameters.

TIMING CONSIDERATIONS (CONT.)

For example, if a 255 (0FF hex) is being sent continuously the receiver would view the data as a DC level. The receiver would hold that level until a transition was required to meet the minimum frequency requirement. If no transition occurred, data integrity could not be guaranteed. Thus, while no particular signal structure or code-balancing requirement is imposed, the designer must make certain that both analog and digital signals have transitions suitable to meet the required transition interval specification so that signal integrity can be reliably insured.

USING THE TXM-xxx-ES FOR ANALOG APPLICATIONS

The ES Series is an excellent choice for sending analog information including audio. The ability of the ES to transmit combinations of analog and digital content opens many new opportunities for design creativity.

Simple or complex analog signals within the specified audio bandwidth and input levels may be connected directly to the transmitters TXDATA pin. The transmitter input is high impedance (500K) and can be directly driven by a wide variety of sources ranging from a single frequency to complex content such as audio.

Analog sources should provide a 0V to no more than 5V P-P maximum waveform and should be AC-coupled into the TXDATA pin. The size of the coupling capacitor should be large enough to insure the passage of all desired frequencies. Since the modulation voltage applied to the TXDATA pin determines the carrier deviation, distortion can occur if the TXDATA pin is over-driven. The actual level of the input waveform should be adjusted to achieve optimum in-circuit results.

USING THE TXM-xxx-ES FOR DIGITAL APPLICATIONS

The ES transmitter is equally capable at accommodating digital data. The transmitter input is high impedance (500K) and can be directly driven by a wide variety of sources including microprocessors and encoder IC's.

When the transmitter will be used to transmit digital data, the TXDATA pin is best driven from a 3-5V source. The transmitter is designed to give an average deviation of 115kHz with a 5V square wave input, and 75kHz with 3V square wave input. Either choice will achieve maximum performance. Data adhering to different electrical level standards such as RS-232 will require buffering or conversion to logic level. In the case of RS-232, such buffering is easily handled with widely available IC's such as the MAX-232 used on the ES master development system.

A TYPICAL SYSTEM EXAMPLE OF DATA TRANSMISSION

To properly apply the ES transmitter, it is critical to understand and respect the differences that exist between a wired and a wireless environment. At every point in this system, there are timing and data-corruption issues that should be understood and taken into account. The following section provides a basic outline of the typical flow of events in a data link incorporating ES-Series modules. While there are many alternate methodologies, this section practically illustrates many of the considerations previously mentioned.

A TYPICAL SYSTEM EXAMPLE (CONT.)

1) Power up transmitter

The transmitter is powered up by bringing VCC to supply voltage and allowing PDN to either float or be pulled up to supply. (PDN uses an internal pull-up resistor and does not require voltage to enable the transmitter). Once the transmitter is enabled, the PLL will begin trying to lock.

2) Wait for transmitter to stabilize

This step is necessary to allow the transmitter time to lock and stabilize. Several options are available during this time. The designer might choose to set a fixed delay equal to the worst-case stabilization time before sending data. Another method would be to send data immediately, knowing that it would not be valid until the transmitter had stabilized. Depending on packet size, the latter method may achieve faster turnaround times but would require more care from a protocol standpoint.

3) Transmit a packet

Structuring the data to be sent into small packets is highly recommended. That way, errors can be managed easily without affecting large amounts of data. Packets should be transmitted so that there is no space between bytes. When using a UART the following packet format is generally followed:

[uart sync byte] [start byte] [data packet]

The UART Sync Byte is used to ensure that the start-bit for the start byte will be accurately detected. It is a single byte with a value of 255 (0FF hex).

A Start Byte often follows the Sync Byte to intelligently qualify the Data Packet which will follow. Detection of the Start Byte would be performed by the computer or microcontroller connected to the receiver.

Let's consider the packet format outlined above after being received and sent to a UART. A UART interprets the start-bit of a byte as a 1-0 transition. When the incoming data is 101010 or hash; it is hard to actually find the start bit. This problem is solved by the UART Sync Byte. The purpose of the Sync Byte is to create a high marking period of at least a byte length so that the start bit of the following Start Byte can be correctly recognized.

The Start Byte following the Sync Byte is used by the receiving computer or microcontroller to intelligently identify the beginning of a data packet. The Start Byte value should be chosen so that it does not appear in the data stream. Otherwise, a receiver may "wake up" in the middle of a packet and interpret data in the packet as a valid Start Byte. There are many other, more complicated ways to organize the protocol if this restriction cannot be met.

There is always a possibility of errors from interference or changing signal conditions causing corruption of the data packet, so some form of error checking should be employed. A simple checksum or CRC could be used. Once an error is detected, the protocol designer may wish to simply discard the corrupt data or develop a scheme so actual error correction can take place.

The preceding steps indicate the general events involved on the transmitter side of a simple data link. While the designer's choice of protocol may be significantly different, it must take into account the issues outlined in order to insure product reliability under field conditions.

USING THE DIVIDED CLOCK OUTPUT (/CLK)

When the ES will be used with a microcontroller the divided clock output (/CLK) saves cost and space by eliminating the need for a crystal or other frequency reference for the microprocessor. To use the output simply add a pull-up resistor as described below.

The /CLK pin is an open collector output. An external pull-up resistor (RL) should be connected between this pin and the positive supply voltage. The value of RL is dependent on two factors:

1) Determine clock frequency. If /CLK SEL is open, the /CLK output will be the TX center frequency divided by 1024; if /CLK SEL is grounded, it will be /256.

2) Determine the load capacitance of the PCB plus the microcontrollers input capacitance (CLD).

Using these two factors the value of RL can be easily calculated:

"/256" RL = 1/ fCLKOUT*8*CLD   "/1024" RL = .01/ fCLKOUT*8*CLD

Example: ***Example:***
For /256   1/(916.48/256)x8x5=6.98K   For /1024   .01/(916.48/1024)x8x5=29.7K

USING LVLADJ

The transmitter's output power can be externally adjusted by approximately -65dBm using the LVLADJ pin. This eliminates the need for external attenuation and allows the transmitter's power to be easily adjusted for range control, lower power consumption, or to meet legal requirements. This pin can also be modulated to allow the ES to operate as an AM transmitter; however, this is not recommended since the ES receiver is designed only for FM/FSK recovery and the performance and noise immunity advantages of FM would be lost.

When the LVLADJ pin is open, the output power will be at its maximum and the transmitter will draw 7mA typically. When LVLADJ is at 0V, the output power will be at its minimum and the transmitter will draw 3mA typically.

To set the transmit power at a particular level, simply create a voltage reference at the LVLADJ pin at an appropriate level to achieve the desired output power. The easiest way to accomplish this is with an appropriate value resistor from the LVLADJ pin to ground. This resistor works in combination with the internal supply pull-up to create a voltage divider. Page 3 of this manual features a chart showing typical resistor values and corresponding attenuation levels.

The LVLADJ pin is very useful during FCC testing to compensate for antenna gain or other product-specific issues which may cause the output power to exceed legal limits. Often it is wise to connect the LVLADJ pin to a variable resistor so that the testing lab can precisely adjust the output power to the maximum threshold allowed by law. The resistor's setting-value can then be noted and a fixed resistor substituted for final testing. Even in designs where attenuation is not anticipated it is a good idea to place a resistor pad connected to LVLADJ so that it can be utilized if needed.

For more sophisticated designs LVLADJ may also be controlled by a DAC or digital potentiometer to allow precise and digitally variable output-power control.

In any case where the voltage on the LVLADJ pin will fall below 1.5VDC, a low-value ceramic capacitor (200-4700pF) must be placed from the module's power supply to the LVLADJ pin. This is necessary to meet the module's minimum enable voltage at start-up.

POWER SUPPLY CONSIDERATIONS

Unlike many Linx modules, the ES transmitter does not have an on-board regulator. Therefore, the supply voltage must be carefully controlled to avoid damage to the part. The nominal operating voltage is 3.0V. The transmitter's output power is affected by supply voltage and will vary as much as 3dBm over the allowable supply range.

Figure 11: Suggested supply filter
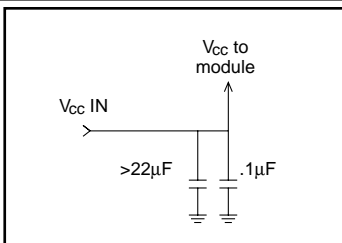
The user must provide a clean source of power to the module to ensure proper operation. Power-supply noise can significantly affect transmitter performance. Providing a clean power supply for the module should be a high design priority.

The module's power-supply line should have bypass capacitors configured as shown in figure 11. Actual values will vary depending on noise conditions.

USING THE PDN PIN

The transmitter's Power Down pin (PDN) can be used to power the transmitter down without the need for an external switch. When the PDN pin is held high or simply left floating, the module will be active and consuming full current. The PDN pin has an internal pull-up and therefore does not require any external components to power-up the module. It is only necessary to pull down the PDN pin if you wish to power down the module. When the PDN pin is pulled to ground the transmitter will enter into a low-current (<95uA) powerdown mode. During this time the transmitter is off and cannot perform any function. The startup time coming out of powerdown will be the same as applying Vcc. This handy pin allows easy control of the transmitter state directly from external components such as microcontroller or keypad.

USING THE LO V DET PIN

In many instances the transmitter may be employed in a battery-powered device. In such applications it is often useful to be able to sense a low-battery condition, either to signal the need for battery replacement or to power down components which might otherwise operate unpredictably. Normally, this supervisory function would require additional circuitry but the ES transmitter thoughtfully includes the function on-board.

The Low Voltage Detect output pin (LO V DET) works in the following manner. When the supply voltage to the ES transmitter falls below a typical threshold of 2.15VDC, the LO V DET pin will transition low. This output can be tied directly to the module's PDN pin to shut off the transmitter, or used to indicate the low-voltage condition to an external circuit or microprocessor. The output could also be used to provide a visual indication of the low-power condition via an LED although a buffer transistor would generally be required to provide an adequate drive level.

The output can also be monitored in mains-powered applications as a safeguard against brownout conditions.

BOARD LAYOUT CONSIDERATIONS

If you are at all familiar with RF devices, you may be concerned about specialized layout requirements. Fortunately, because of the care taken by Linx in the ES-Series design, integrating the transmitter into your own product is very straightforward. Despite this ease of application it is still wise to maintain respect for the RF stage and exercise appropriate care in layout and application in order to maximize performance and assure reliable operation.

Here are a few basic design and layout rules, which will help you enjoy a trouble-free path to RF success.

Figure 12 shows the suggested PCB footprint for the ES-Series transmitter. This footprint is suitable for hand- or reflow-assembly techniques.
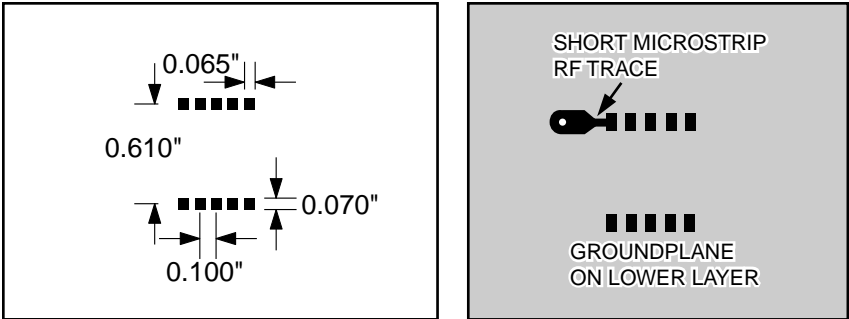

Figure 12: Recommended pad geometry and PCB layout

During prototyping the module should be soldered to a properly laid-out circuit board. The use of prototyping or "perf" boards is strongly discouraged.

No PCB traces or vias should be placed underneath the transmitter module on the PCB layer contacting the module. A groundplane (as large as possible) should be placed on a lower layer of the PCB under the ES transmitter. This groundplane can also be critical to the performance of your antenna. The groundplane's effect as an antenna counterpoise will be discussed in greater detail in later sections.

The ES should, as much as reasonably possible, be isolated from other components on your PCB, especially high-frequency circuitry such as crystal oscillators, switching power supplies and high-speed bus lines. Make sure internal wiring is routed away from the module and antenna, and is secured to prevent displacement.
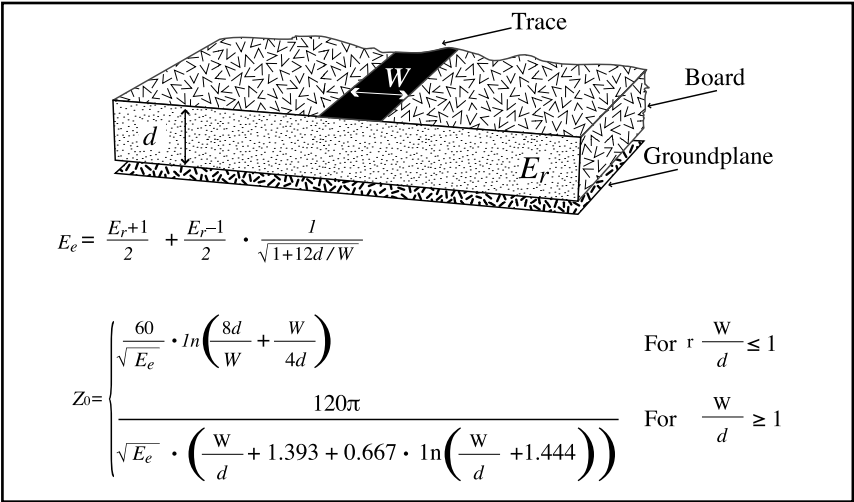
The power-supply filter components should be placed close to the Vcc line.

In some instances, a designer may wish to encapsulate or "pot" the product. Many Linx customers have done this successfully; however, there are a wide variety of potting compounds with varying dielectric properties. Since such compounds can considerably impact RF performance it is the designer's responsibility to carefully evaluate the impact of such materials.

The trace from the transmitter to the antenna should be kept as short as possible. A simple trace is suitable for runs up to 1/8 inch for antennas with wide bandwidth characteristics. For longer runs or to avoid detuning narrow bandwidth antennas such as a helical, use a 50-ohm coax or 50-ohm microstrip transmission line as described in the following section.

MICROSTRIP DETAILS

A transmission line is a medium whereby RF energy is transferred from one place to another with minimal loss. This is a critical factor, particularly in high-frequency products like the ES, because the trace leading to the module's antenna can effectively contribute to the length of the antenna, changing its resonant bandwidth. In order to minimize loss and detuning, some form of transmission line between the antenna and the module is needed, unless the antenna connection can be made in close proximity: <1/8 in. to the module. One common form of transmission line is coax cable, another is the *microstrip*. This term refers to a PCB trace running over a groundplane which is designed to serve as a transmission line between the module and the antenna. The width is based on the desired characteristic impedance, the thickness of the PCB, and its dielectric constant. For standard .062 thick FR-4 material, the trace width would be 111 mils. The correct trace width can be calculated for other widths and materials using the information below.

$$E_e = \frac{E_r+1}{2} + \frac{E_r-1}{2} \cdot \frac{1}{\sqrt{1+12d/W}}$$

$$Z_0 = \begin{cases} \dfrac{\dfrac{60}{\sqrt{E_e}} \cdot In\left(\dfrac{8d}{W} + \dfrac{W}{4d}\right)}{} & \text{For } r \; \dfrac{W}{d} \le 1 \\[4ex] \dfrac{120\pi}{\sqrt{E_e} \cdot \left(\dfrac{W}{d} + 1.393 + 0.667 \cdot 1n\left(\dfrac{W}{d} + 1.444\right)\right)} & \text{For } \dfrac{W}{d} \ge 1 \end{cases}$$

Dielectric Constant	Width/Height (W/d)	Effective Dielectric Constant	Characteristic Impedance
4.8	1.8	3.59	50.0
4	2	3.07	51.0
2.55	3	2.12	48.0

Figure 13: Microstrip formulas (Er = Dielectric constant of pc board material)

ANTENNA CONSIDERATIONS

The choice of antennas is one of the most critical and often overlooked design considerations. The range, performance, and legality of an RF link is critically dependent upon the type of antenna employed. Proper design and matching of an antenna is a complex task requiring sophisticated test equipment and a strong background in the principles of RF propagation. While adequate antenna performance can often be obtained by trial and error methods, you may also want to consider utilizing a premade antenna from Linx. Our low-cost antenna line is designed to ensure maximum performance and Part-15 compliance. The purpose of the following sections is to give you a basic idea of some of the considerations involved in the design and selection of antennas. For a more comprehensive discussion please review Linx applications note #00500 "Antennas: Design, Application, Performance".

GENERAL ANTENNA RULES

An antenna allows RF energy to be efficiently conveyed to and from free space. The antenna should give its optimum performance in the band of use and capture as little as possible of other off-frequency signals. It is important to recognize that the antenna plays a significant role in determining the performance and legality of your end product. In order to gain a better understanding of the considerations involved in the design and selection of antennas, please review Linx applications note #00500 "Antennas: Design, Application, Performance".

It is usually best to utilize a basic 1/4-wave whip for your initial concept evaluation. Once the prototype product is operating satisfactorily, a production antenna should be selected to meet the cost, size and cosmetic requirements of the product.

Maximum antenna efficiency is always obtained when the antenna is at resonance. If the antenna is too short, capacitive reactance is present; if it is too long, inductive reactance will be present. The indicator of resonance is the minimum point in the VSWR curve. You will see from the adjoining example that antenna (A) is resonant at too low a frequency, indicating excessive length, while antenna (C) is resonant at too high a frequency, indicating the antenna is too short. Antenna (B), however, is "just right."

Antenna resonance should not be confused with antenna impedance. The difference between resonance and impedance is most easily understood by considering the value of VSWR at its lowest point. The lowest point of VSWR indicates the antenna is resonant, but the value of that low point is determined by the quality of the match between the antenna, the transmission line, and the device to which it is attached.

DESIRED FREQUENCY

A   B   C
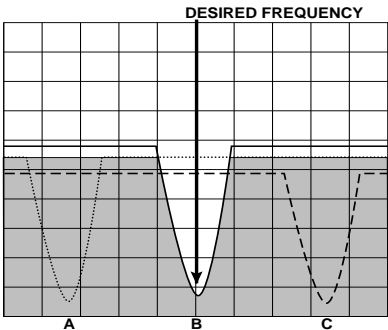
To fully appreciate the importance of an antenna that is both resonant and matched, consider that an antenna with a VSWR of 1.5 will effectively transmit approximately 95% of its power, while an antenna with a VSWR of 10 will only transmit about 30%.

GUIDELINES FOR OPTIMUM ANTENNA PERFORMANCE

1. Proximity to objects such as a user's hand or body, or metal objects will cause an antenna to detune. For this reason, the antenna shaft and tip should be positioned as far away from such objects as possible.

2. Optimum performance will be obtained from a 1/4- or 1/2-wave straight whip mounted at a right angle to the groundplane. In many cases, this isn't desirable for practical or ergonomic reasons; thus, an alternative mounting position or antenna style may be utilized.

3. If an internal antenna is to be used, keep it away from other metal components, particularly large items like transformers, batteries, and PCB tracks and groundplanes. In many cases, the space around the antenna is as important as the antenna itself. Objects in close proximity to the antenna can cause direct detuning while those farther removed will alter the antenna's pattern and symmetry.
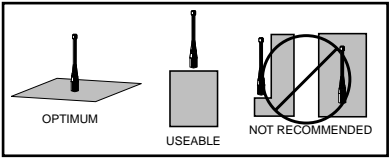

Figure 14: Groundplane Orientation

4. In many antenna designs, particularly 1/4-wave whips, the groundplane acts as a counterpoise, forming, in essence, a 1/2-wave dipole. For this reason adequate groundplane area is essential. The groundplane can be a metal case or ground-fill on the circuit board. Ideally, the antenna would be centered on the groundplane to be used as counterpoise and its surface area would be $\geq$ the overall length of the 1/4-wave radiating element. This is often not practical due to size and configuration constraints. In these instances the designer must make the best use of the area available to create as much groundplane in proximity to the base of the antenna as possible. When such compromises are necessary it should be recognized that the range and reliability of the link can be significantly affected.

5. In some applications it is advantageous to place the RF module and its antenna away from the main equipment. This avoids interference problems and allows the antenna to be oriented for optimum RF performance. Always use 50Ω coax such as RG-174 for the remote feed. If the antenna is not in close proximity to a circuit board plane or grounded metal case, a small metal plate may be fabricated to maximize antenna performance.
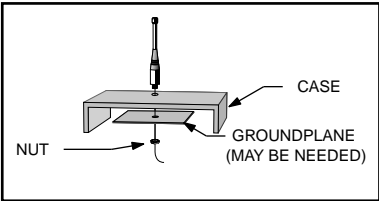

Figure 15: Remote Groundplane

6. Remove the antenna as far as possible from potential interference sources. There are many possible sources of internally generated interference. Switching power supplies, oscillators, even relays can also be significant sources of potential interference. Remember, the single best weapon against such problems is attention to placement and layout. Filter the module's power supply with a high-frequency bypass capacitor. Place adequate groundplane under all potential sources of noise. Shield noisy board areas when practical.

COMMON ANTENNA STYLES

The antenna is a critical and often overlooked component which has a significant effect on the overall range, performance and legality of an RF link. There are hundreds of antenna styles that can be successfully employed with the ES Series. Following is a brief discussion of styles commonly utilized in compact RF designs. Additional antenna information can be found in Linx application notes #00500, #00100, #00126 and #00140.

Whip Style
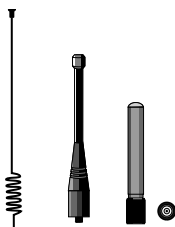
A whip-style monopole antenna provides outstanding overall performance and stability. A low-cost whip can be easily fabricated from wire or rod, but most product designers opt for the consistent performance and cosmetic appeal of a professionally made model. To meet this need, Linx offers a wide variety of straight and reduced-height whip-style antennas in permanent and connectorized mounting styles.

The wavelength of the operational frequency determines an antenna's overall length. Since a full wavelength is often quite long, a partial 1/4-wave antenna is normally employed. Its size and natural radiation resistance make it well matched to Linx modules. The approximate length for a straight 1/4-wave antenna can be easily found using the formula below. It is also possible to reduce the overall height of the antenna by using a helical winding; therefore, physical appearance is not always an indicator of the antennas frequency.

1/4-wave wire length frequencies:
433MHz = 6.5"
868MHz = 3.24"
902-928MHz = 3.06"

$$L = \frac{234}{F_{MHz}}$$

Where:
L=length in feet of quarter-wavelength
F=operating frequency in megahertz

Example:
$$\frac{234}{916MHz} = .255$$
.255 x 12" = 3.06"

Specialty Styles

Linx offers a wide variety of specialized antenna styles and variations. Many of these styles utilize helical elements to reduce the overall antenna size while maintaining excellent performance characteristics. A helical antenna's bandwidth is often quite narrow and the antenna can detune in proximity to other objects, so care must be exercised in layout and placement.

Loop Style

A loop- or trace-style antenna is normally printed directly on a product's PCB. This makes it the most cost-effective of antenna styles. The element can be made self-resonant or externally resonated with discrete components but its actual layout is usually product specific. Despite its cost advantages, PCB antenna styles are generally inefficient and useful only for short-range applications. Loop-style antennas are also very sensitive to changes in layout or substrate dielectric which can introduce consistency issues into the production process. In addition, printed styles initially are difficult to engineer, requiring the use of expensive equipment including a network analyzer. An improperly designed loop will have a high SWR at the desired frequency which can introduce instability in the RF stages.

Linx offers a low-cost planar antenna called the "SPLATCH" which is an excellent alternative to the sometimes problematic PCB trace style. This tiny antenna mounts directly to a product's PCB and requires no testing or tuning. Its design is stable and it provides excellent performance in light of its compact size.
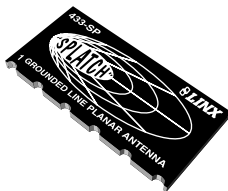
PRODUCTION GUIDELINES

The ES modules are packaged in a hybrid SMD package which has been designed to support hand- or automated-assembly techniques. Since the ES device contains discrete components internally, the assembly procedures are critical to insuring the reliable function of the ES product. The following procedures should be reviewed with and practiced by all assembly personnel.

TRANSMITTER HAND ASSEMBLY

The ES Transmitter's primary mounting surface is ten pads located on the bottom of the module. Since these pads are inaccessible during mounting, plated castellations that run up the side of the module have been provided to facilitate solder wicking to the module's underside. This allows for very quick and efficient hand soldering for prototyping and small volume production.

If the recommended pad placement has been followed, the pad on the board will extend slightly past the edge of the module. Touch both the PCB pad and the module castellation with a fine soldering tip. Tack one module corner first, then work around the remaining attachment points using care not to exceed the solder times listed below.
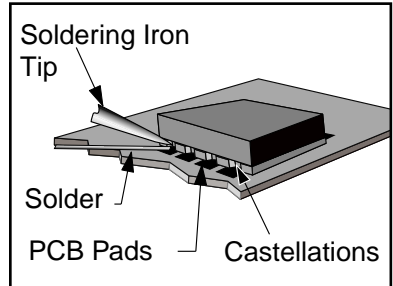

Figure 16: Soldering Technique

Note:

Care should be taken, especially when hand-soldering, not to use excessive amounts of flux as it will wick under the module and potentially cause irregularity in its function. In most cases, no-clean flux is the best choice

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Absolute Maximum Solder Times

Hand-Solder Temp. TX +225°C for 10 Sec.
Hand-Solder Temp. RX +225°C for 10 Sec.
Recommended Solder Melting Point +180°C
Reflow Oven: +220° Max. (See adjoining diagram)

TRANSMITTER AUTOMATED ASSEMBLY

For high-volume assembly, most users will want to auto-place the modules. The modules have been designed to maintain compatibility with most pick-and-place equipment; however, due to the module's hybrid nature certain aspects of the automated assembly process are far more critical than for other component types.

Following are brief discussions of the three primary areas where caution must be observed.

Reflow Temperature Profile

The single most critical stage in the automated assembly process is the reflow process. The reflow profile below should not be exceeded since excessive temperatures or transport times during reflow will irreparably damage the modules. Assembly personnel will need to pay careful attention to the oven's profile to insure that it meets the requirements necessary to successfully reflow all components while remaining within the limits mandated by the modules themselves.
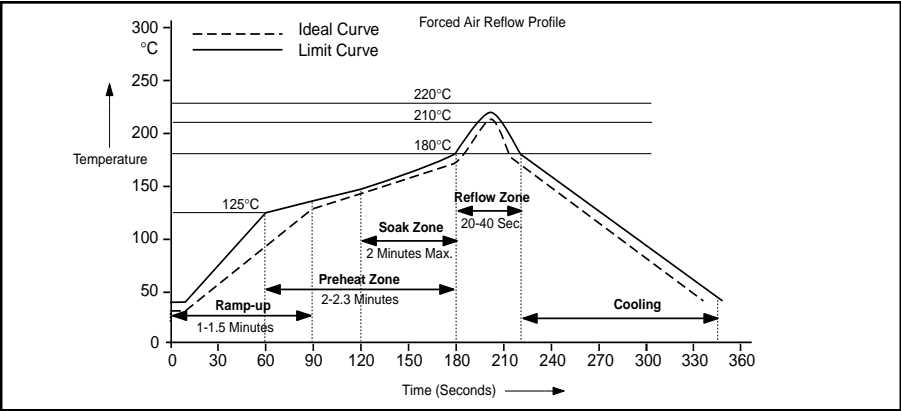

Figure 17: Maximum reflow profile

Shock During Reflow Transport

Since some internal module components may reflow along with the components placed on the board being assembled, it is imperative that the module not be subjected to shock or vibration during the time solder is liquidus.

Washability

The modules are wash resistant, but are not hermetically sealed. Linx recommends wash-free manufacturing techniques; however, the modules can be subject to a wash cycle provided that a drying time is allowed prior to applying electrical power to the parts. The drying time should be sufficient to allow any moisture which may have migrated into the module to evaporate, thus eliminating the potential for shorting damage during power-up or testing.

LEGAL CONSIDERATIONS

NOTE: ES Series Modules are designed as component devices which require external components to function. The modules are intended to allow for full Part-15 compliance; however, they are not approved by the FCC or any other agency worldwide. The purchaser understands that approvals may be required prior to the sale or operation of the device, and agrees to utilize the component in keeping with all laws governing its operation in the country of operation.

When working with RF, a clear distinction must be made between what is technically possible and what is legally acceptable in the country where operation is intended. Many manufacturers have avoided incorporating RF into their products as a result of uncertainty and even fear of the approval and certification process. Here at Linx ,our desire is not only to expedite the design process, but also to assist you in achieving a clear idea of what is involved in obtaining the approvals necessary to legally market your completed product.

In the United States, the approval process is actually quite straightforward. The regulations governing RF devices and the enforcement of them are the responsibility of the Federal Communications Commission. The regulations are contained in the Code of Federal Regulations (CFR), Title 47. Title 47 is made up of numerous volumes; however, all regulations applicable to this module are contained in volume 0-19. It is strongly recommended that a copy be obtained from the Government Printing Office in Washington, or from your local government book store. Excerpts of applicable sections are included with Linx evaluation kits or may be obtained from the Linx Technologies web site (www.linxtechnologies.com). In brief, these rules require that any device which intentionally radiates RF energy be approved; that is, tested for compliance and issued a unique identification number. This is a relatively painless process. Linx offers full EMC pre-compliance testing in our HP/Emco-equipped test center. Final compliance testing is then performed by one of the many independent testing laboratories across the country. Many labs can also provide other certifications the product may require at the same time, such as UL, CLASS A/B, etc. Once your completed product has passed, you will be issued an ID number which is then clearly placed on each product manufactured.

Questions regarding interpretations of the Part-2 and Part-15 rules or measurement procedures used to test intentional radiators should be addressed to:

Federal Communications Commission
Equipment Authorization Division
Customer Service Branch, MS 1300F2
7435 Oakland Mills Road
Columbia, MD 21046

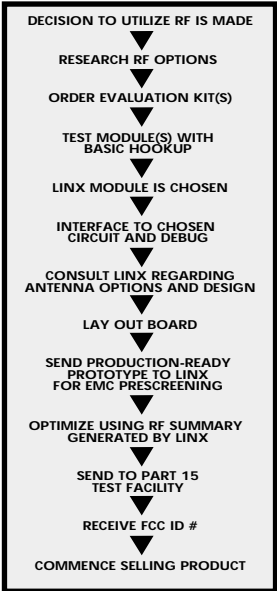Tel: (301) 725-1585 / Fax: (301) 344-2050 E-Mail: labinfo@fcc.gov

International approvals are slightly more complex, although many modules are designed to allow all international standards to be met. If you are considering the export of your product abroad, you should contact Linx Technologies to determine the specific suitability of the module to your application.

All Linx modules are designed with the approval process in mind and thus much of the frustration that is typically experienced with a discrete design is eliminated. Approval is still dependent on many factors such as the choice of antennas, correct use of the frequency selected, and physical packaging. While some extra cost and design effort are required to address these issues, the additional usefulness and profitability added to a product by RF makes the effort more than worthwhile.

ACHIEVING A SUCCESSFUL RF IMPLEMENTATION

Adding wireless capabilities brings an exciting new dimension to any product. It also means that additional effort and commitment will be needed to bring the product successfully to market. By utilizing Linx RF modules, the design and approval process will be greatly simplified. It is important, however, to have an objective view of the steps necessary to insure a successful RF integration. Since the capabilities of each customer vary widely, it is difficult to recommend one particular design path, but most projects follow steps similar to those shown at the right.

In reviewing this sample design path you may notice that Linx offers a variety of services, such as antenna design, and FCC prequalification, that are unusual for a high-volume component manufacturer. These services, along with an exceptional level of technical support, are offered because we recognize that RF is a complex science requiring the highest caliber of products and support. "Wireless Made Simple" is more than just a motto, it's our commitment. By choosing Linx as your RF partner and taking advantage of the resources we offer, you will not only survive implementing RF, but you may even find the process enjoyable.

DECISION TO UTILIZE RF IS MADE
▼
RESEARCH RF OPTIONS
▼
ORDER EVALUATION KIT(S)
▼
TEST MODULE(S) WITH BASIC HOOKUP
▼
LINX MODULE IS CHOSEN
▼
INTERFACE TO CHOSEN CIRCUIT AND DEBUG
▼
CONSULT LINX REGARDING ANTENNA OPTIONS AND DESIGN
▼
LAY OUT BOARD
▼
SEND PRODUCTION-READY PROTOTYPE TO LINX FOR EMC PRESCREENING
▼
OPTIMIZE USING RF SUMMARY GENERATED BY LINX
▼
SEND TO PART 15 TEST FACILITY
▼
RECEIVE FCC ID #
▼
COMMENCE SELLING PRODUCT

TYPICAL STEPS FOR IMPLEMENTING RF

HELPFUL APPLICATION NOTES FROM LINX

It is not the intention of this manual to address in depth many of the issues that should be considered to ensure that the modules function correctly and deliver the maximum possible performance. As you proceed with your design you may wish to obtain one or more of the following application notes, which address in depth key areas of RF design and application of Linx products.

NOTE #	LINX APPLICATION NOTE TITLE
00100	RF 101: Information for the RF-challenged
00102	RS-232: A brief overview
00125	Considerations for operation within 260-470 band
00130	Modulation techniques for low-cost RF data links
00126	Considerations for operation in the 902 Mhz to 928 Mhz band
00140	The FCC Road: Part 15 from concept to approval
00150	Use and design of T-Attenuation Pads
00500	Antennas: Design, Application, Performance

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