

New standards and certified modules ease low-power-radio designs



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Europe's new 868- to 870-MHz licence-free band encourages the trend to a "more professional" class of wireless-link design. Designers can now implement wireless links using precertified modules without mastering RF design or grappling with type-approval procedures.

Short-range radio devices, unlicensed low-power radios, wireless data links—whatever you call them, demand for such devices is booming. The potential market is as large as that for telephone handsets—but regulation of spectrum utilisation and appropriate access technology must occur before these devices achieve such market penetration.

The cost and performance of these devices range from vehicle-access key fobs, which cost a few pounds for 2 kbps at 10m, to wireless-LAN and telemetry interfaces, costing hundreds of pounds for 1 Mbps at 3 km. The ability to act at a distance—or get up-to-date information minute-by-minute from remote sites—is the key advantage these devices offer. Business benefits include improved safety in hazardous operations, better quality of service, lower inventories, and increased productivity of mobile plants and staff. Social benefits are shorter response times to emergencies and improved security for homes and public places.

But questions remain about how to develop a wireless link that satisfies various national regulatory authorities, even within a single market such as the European Union, and how to locate a good RF designer to join your team. You cannot pretend that these

Photo courtesy Consumer Microcircuits

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problems have been solved completely, but recent developments in spectrum allocation, standards, and technology have lowered some of the hurdles that equipment designers must clear when targeting European markets.

Available technology now lets an application team build a wireless-linked system without an RF designer. This development is welcome news, given the difficulty of recruiting RF specialists. However, without an in-house RF designer, you still need access to some RF knowledge for top-level system design.

Designers also need to keep close

@ a glance

- The 43 member countries of the CEPT are steering unlicensed wireless links into application-specific frequency bands.
- Suppliers offer both complete interface modules and ICs for the telemetry, telecommand, and alarm bands at 433 MHz, 868 MHz, and 2.4 GHz.
- Designing with ICs provides equipment with wireless capability for \$5 to \$50. Although modules cost more, they save scarce RF-design resources and usually confer automatic type approval on the equipment in which they serve.

watch on the Pan-European regulatory environment: frequency allocation is the province of the Conference Europeenne des Administrations des Postes et des Telecommunications (CEPT), whereas equipment standards are the concern of the European Telecommunications Standards Institute (ETSI). It is vital to understand which bits of the spectrum are available for your application in the national markets you seek to penetrate, but be aware that this quest for understanding is a moving target. Fortunately, new recommendations and standards are now being published in formats

TABLE 1—REPRESENTATIVE WIRELESS-INTERFACE ICs

Vendor	Part	Function	Frequency	Output, sensitivity	Power supply (V)	Price (10,000)
BethelTronix Circle No. 506	BT1072CL	I,Q input and 10.7-MHz IF-output transceiver	850 to 950 MHz	5 mW, -108 dBm	2.7 to 3.3	\$6.85
	BT10731B	I,Q input transmitter	800 to 1000 MHz	5 mW	2.7 to 3.3	\$3.75
	BT10732B	10.7-MHz IF-output receiver	850 to 950 MHz	-108 dBm	2.7 to 3.3	\$3.75
Consumer Microcircuits Circle No. 508	FX909A	GMSK packet modem with FEC, CRC, and interleaving; Mobitex compatible	To 19.2 kbps	Not applicable	3 to 5.5	\$10.30
	FX929B	FSK packet modem with FEC, CRC, and interleaving; RD-LAP compatible	To 19.2 kbps	Not applicable	3 to 5.5	\$12.90
Harris Circle No. 510	HFA3724, HFA3524, HFA3424, HFA3935	IF converter and I,Q modem, upconverter/downconverter, RF-input amp, power amp, and transmitting/receiving switch	2.4 to 2.5 GHz	12.5 mW, -93 dBm	2.7 to 5.5	\$33.50
	HFA3834	Baseband direct-sequence spread-spectrum processor	To 4 Mbps	Not applicable	2.7 to 5.5	\$7
Maxim Circle No. 513	MAX2402	Digital-input BPSK transmitter	800 to 1000 MHz	100 mW	5	Not available
Nordic Circle No. 515	nRF0433	Digital-I/O FSK transceiver	418 MHz, 434 MHz	10 mW, -105 dBm	4.75 to 5.25	\$8.45
Philips Circle No. 516	UAA3201T	Digital-output ASK receiver	150 to 450 MHz	-105 dBm	3.5 to 6	\$1.30
	UAA3202M	Digital-output FSK receiver	150 to 450 MHz	-94 dBm	3.5 to 6	\$1.30
Thesys Circle No. 520	TH7101	Digital-input ASK transmitter	400 to 500 MHz	4 mW	2.5 to 7	\$1.55
	TH7106	Digital-input FSK transmitter	400 to 500 MHz	4 mW	3	\$1.75
Thomson Circle No. 521	TRX01	Half-duplex ASK/FSK transceiver	300 to 330 MHz, 400 to 465 MHz, 800 to 930 MHz	10 mW, -105 dBm	2.4 to 5.5	\$8

Notes: GMSK=Gaussian-filtered minimum-shift keying.
I,Q=in phase and quadrature.
CRC=cyclic-redundancy check.
FEC=forward error correction.
BPSK=binary phase-shift keying.
ASK=amplitude shift keying.



that clarify design requirements. What's more, you can download them directly from the Internet: For CEPT material, go to www.ero.dk, and for ETSI information, see www.etsi.fr.

National authorities, such as the

United Kingdom's Radiocommunications Agency or Germany's Bundesamt für Post und Telekommunikation, are responsible for implementing these recommendations, and they may place restrictions on designing and operating

wireless links within their boundaries. A list of contacts for these authorities is available from the Low Power Radio Association (LPRA) (see **box "Contacting the Low Power Radio Association"**).

If you want to design wireless-link

EUROPEAN SPECTRUM REGULATION AND TECHNICAL STANDARDS

The European Radiocommunications Committee (ERC) of the CEPT agrees on recommendations that authorities in 43 European member countries implement. CEPT/ERC recommendation 70-03, "Relating to the use of short range devices (SRDs)," published in October 1977, has four main points:

- SRDs should operate on a licence-free basis in defined frequency bands. These units are not permitted to interfere with licenced radio services, nor may they claim protection from licenced services.
- Different applications should have their own pattern of spectrum allocation and operation restrictions. Such stipulations are set out in document annexes.
- Member countries should accept conformity assessments of SRD equipment performed in other member countries as well as type testing to ETSI standards carried out in any accredited laboratory.
- SRDs conforming to the annexes should circulate freely in trade and use, except where national restrictions (listed in the appendix) apply. The existence and exact status of national restrictions must be verified with relevant national authorities.

Note that last sentence. Designing a product to conform to this recommendation promises a good chance of being able to widely distribute the product in Europe, but designers should check with the authorities in the key market countries

before spending that budget.

You can download the entire text of the recommendation, including annexes and appendices, from the European Radio Organisation's Web site, www.ero.dk. The Web site provides a summary of frequency bands between 100 MHz and 2.5 GHz recommended for nonspecific telecommand and telemetry links, as well as for alarm systems. Lower harmonised frequency bands for these applications, 27 and 40 MHz, are shared with model remote controllers. Higher bands exist at 5.8 and 24 GHz. However, **Table A** covers bands where new technical implementation and commercial exploitation are most active.

Note that these applications are not intended to include audio signals, although an annex allocating 863- to 865-MHz to wireless headsets is under discussion. The current recommendation allows video signals, but only above 2.4 GHz.

ETSI publishes technical standards governing type testing of SRDs. You can locate them on the Web at www.etsi.fr. ETS 300 220 is the relevant standard for SRDs operating between 25 MHz and 1 GHz. This standard prescribes test methods and limits for transmit functions (frequency accuracy, radiated power, adjacent-channel power, or wide-band edge level) and radiated power from receivers. Currently under discussion are further limits on receivers, such as sensitivity and degradation by cochannel, adjacent channel, and spurious signals. Wireless-LAN devices operating in the 2.4- to 2.5-GHz band are governed by ETS 300 328.

TABLE A—CEPT 70-03 DATA AND ALARM FREQUENCY BANDS

Band	Power (mW)	Duty cycle (%)	Channels	Comments
433.05 to 434.79 MHz	10	Not available	No restriction	
868.0 to 868.6 MHz	25	1	25 kHz (or spread spectrum or wideband)	
868.6 to 868.7 MHz	10	0.1	25 kHz	Only alarm systems
868.7 to 869.2 MHz	25	0.1	25 kHz (or spread spectrum or wideband)	
869.2 to 869.3 MHz	10	0.1	25 kHz	Also alarm systems
869.3 to 869.4 MHz	To be determined	To be determined	25 kHz	
869.4 to 869.65 MHz	500	10	25 or 250 kHz	
869.65 to 869.7 MHz	25	10	25 kHz	Only alarm systems
869.7 to 870 MHz	5	100	25, 50, or 300 kHz	
2.4 to 2.4835 GHz	10	Not available	No restriction	Video permitted; also radio LANs at 100 mW; movement detection at 25 mW
2.446 to 2.454 GHz	500	Not available	1.5 MHz	Railway-vehicle identification

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functions into your equipment, you have two main approaches. First, if you have in-house RF expertise, you can design your own interface using ICs; a single chip may provide a complete solution, but otherwise you should consider a partial or complete chip set for wireless-LAN or telephony applications. Second, you can buy a complete interface module from a specialist supplier. Obviously, your material cost increases significantly with the latter option, but there are several advantages to selecting this route:

- You may not need an RF designer on the product team—although for some development stages you may opt for a consultant.
- The module may already be type-approved for use in CEPT markets.



This wireless terminal has an integral bar-code reader for one-handed operation (courtesy Belgravium Ltd).

However, the complete product still must achieve EMC compliance for CE marking.

- You may achieve faster time to market and better application focus.

Table 1 lists representative wireless-interface chips and chip sets—as well as guide prices. Output power is normally at chip output into a 50Ω load, and sensitivity is at chip input for a 3% bit-

TABLE 2—SAMPLE WIRELESS-INTERFACE MODULES

Vendor	Part	Function	Frequency	Range	Power supply (V)	Price (100)
Circuit Design Inc Circle No. 507	CDP-RX-03S	Digital-output 4800-bps FSK receiver	868 to 870 MHz	Not available	5 to 14	Not available
	CDP-TX-03S	Digital-input 4800-bps FSK transmitter	868 to 870 MHz	Not available	5 to 14	Not available
	STD-500	Digital-I/O 64-kbps, 16-channel, spread- spectrum transceiver	2.4 to 2.5 GHz	100m	3 to 9	Not available
HM-Funktechnik Circle No. 511	70RX-S	FM receiver, 138 switch/ software 12.5-kHz channels in 1.73-MHz band	410 to 470 MHz	500m	5 to 12	\$88
	70TX-S	FM transmitter, 138 switch/software 12.5-kHz channels in 1.73-MHz band	410 to 470 MHz	500m	5 to 12	\$66
	TV-95	Transmitter for composite video, 5-MHz bandwidth; frequency converter to view on standard TV.	2.4 to 2.5 GHz	1 km	5 to 12	\$660
Radiometrix Circle No. 517	BiM418F, BiM433F	Digital-I/O transceiver	418 MHz, 434 MHz	120m	4.5 to 5.5	\$18.20
	RX2	Digital/audio- output receiver	418 MHz, 434 MHz	300m	3 to 6	\$12.10
	TX2	Digital/audio-input transmitter	418 MHz, 434 MHz	300m	2.2 to 6	\$6.10
Wood and Douglas Circle No. 522	RSX series	80-channel VHF or UHF wireless RS-232C 9600-bps modem with FEC	100 to 190 MHz, 400 to 450 MHz	5 km	5.5 to 9, 9 to 12	Modem \$800
	RTC450, RRC450	Transmitting, receiving modules with 10 remote-control relays	400 to 500 MHz	Not available	11 to 15	Modules \$1500

Note: FEC=forward error correction.

error rate (BER) on FSK signals.

Devices designed for the 434-MHz band typically suit digital data transfers to or from a μ C. So, the chip user has to design any forward-error-correction (FEC) or cyclic-redundancy-check (CRC) coding scheme and interleaving process in software.

Devices serving the new 868- to 870-MHz band are just emerging, and designers will be able to choose between digital-I/O devices and those accepting the baseband signals a modem produces. Representative FSK and Gaussian-filtered minimum-shift keying (GMSK) modems appear in **Table 1**. Available modems produce packeted data compatible with commercial wireless-data-network formats, such as Ericsson's (www.ericsson.com) Mobitex or Motorola's RD-LAP.

Serving the 2.4- to 2.5-GHz band, Harris' chip set is designed for half-duplex wireless-LAN use. Full-duplex chips are also available—but at greater cost. The baseband processor converts between digital data (as much as 4 Mbps) and analog in-phase and quadrature (I,Q) signals using differential binary or quad phase-shift keying (PSK) for direct-sequence spread-spectrum signals. These signals are authorised under CEPT/ERC recommendation 70-03, which does not impose a channel structure on the 2.4- to 2.4835-GHz band. For a list of additional telecommunications-IC manufacturers offering chips for this frequency band, see **box "For more information..."**.

If you opt for the packaged-interface-module route, you'll discover a far wider selection from which to choose. The cheapest modules provide basic transmitting or receiving functions and can be extremely compact. More sophisticated units offer RS-232C telemetry, video links (duplex for pan and zoom), or remote control as drop-in or bolt-on options.

CONTACTING THE LOW POWER RADIO ASSOCIATION

The Low Power Radio Association (LPRA) is a Pan-European forum comprising wireless-product suppliers and users. The LPRA holds exhibitions, sponsors conferences, and makes presentations to regulatory and standard-setting authorities.

The organisation also publishes a quarterly newsletter and a yearbook listing member companies and contacts of all national authorities implementing CEPT and ETSI decisions. Proceedings of the LPRA's October 1997 conference are still available and contain, inter alia, articles on design issues by Graham Sharples of RadioMetrix and Alan Wood of Wood & Douglas.

You can contact the LPRA at Brearley Hall, Luddenden Foot, Halifax HX2 6HS, UK, +44 1422 886463, www.lpra.org.

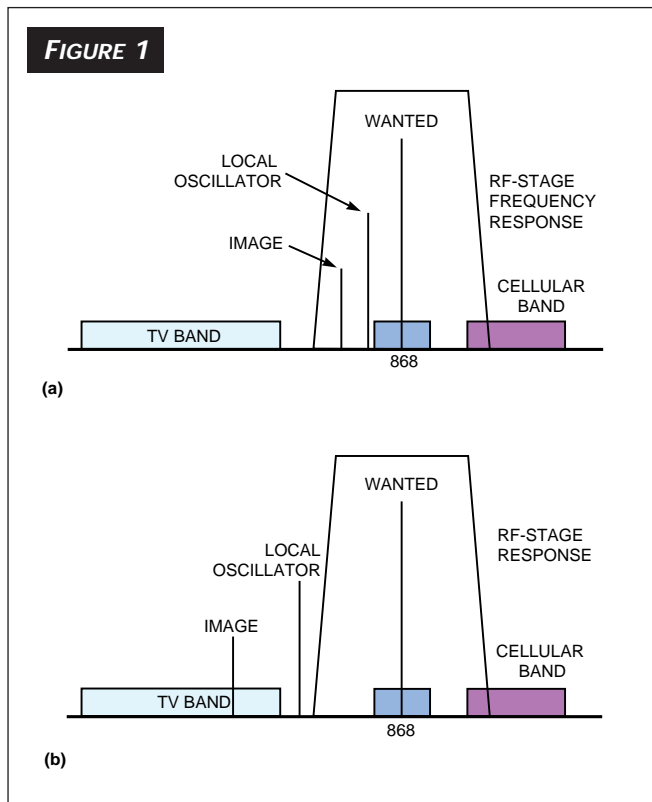
Table 2, based on manufacturers' data sheets, provides a small sample of available module offerings; the **table** also offers guide prices. Note that maximum range in clear air may be at transmitter power above CEPT/ERC 70-03-recommended levels.

Step 1: system design

Primary issues system designers must address include communication mode, channel usage, operating range, peak data rate, and reliability. Such

considerations determine the suitable frequency ranges available to your application. However, make sure to create a clear statement of who will send how much of what to whom—and when. Also, try to determine what quality of service users expect. If you lack definitive answers to these questions, you're not yet ready for the design process. And, remember that if you don't have ready access to RF expertise, you will likely benefit from a consultant. Consider the following:

- Communication modes are simplex (one-way traffic, such as vehicle keys and garage-door openers), half-duplex (traffic in alternate directions for polled telemetry and alarm systems, as well as command and acknowledge), or full-duplex (simultaneous two-way traffic, as in mobile telephones).
- How many channels will you use? Having the ability to select one of several channels adds cost and complexity, but traffic density or interfering signals may force this feature on you.
- How will you deal with collisions between multiple transmitters? Remember that, although your base station must detect signals from any out station, there is no guarantee that an out station can hear all others. Obviously, a system



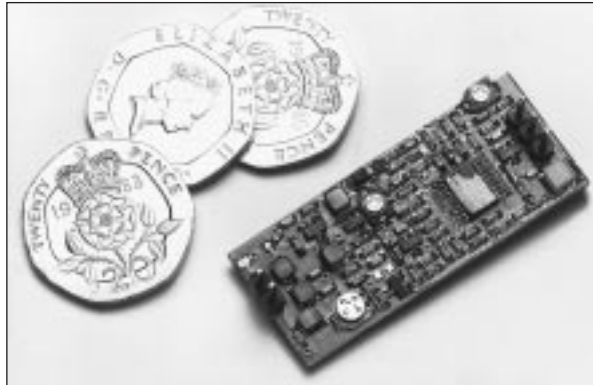
Low IF folds image frequency into RF passband (a); high IF folds image frequency beyond RF passband (b).

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in which out stations speak only when spoken to can get by with one channel and no collision problems.

- Operating range, transmission power, and antenna requirements are inter-linked. Ballpark figures for transmitters in the 1- to 10-mW range span 30 to 500m outdoors and 10 to 100m within buildings.

By now you probably have identified a number of eligible frequency bands. If you're designing a system for a particular locality, a survey of the RF environment will help. If your system will be used in other countries, check the national limitations on frequency usage. Or, if material cost is critical, you may opt for the lowest eligible frequency. But if reliability of first-time



A 10-mW transmitter module can be very compact (courtesy Advanced Technology (UK) PLC).

communication or high data rates is most important, a move to higher frequency bands may be worthwhile.

According to Graham Sharples, managing director of RadioMetrix, the new European-harmonised 868- to

870-MHz band promises better reception than the existing 433- to 434-MHz band, because of lower density of interfering sources and higher permitted power levels. These features will allow increased range or higher data rates.

Sharples notes, however, that this advantage must be set against higher material cost. Tighter frequency tolerances may require crystal/PLL frequency sources, which together with higher carrier frequencies and IFs increase power consumption. The same factors apply to the 2.4-GHz band, only more so. Increased power consumption, GaAs devices, and spread-spectrum modulation all push up costs.

Although you have set goals for range, data rate, and BER for your sys-

FOR MORE INFORMATION...

For more information on the low-power-radio devices discussed in this article, circle the appropriate numbers on the Information Retrieval Service card, or use *EDN Europe's* Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN Europe*.

Advanced Technology
(UK) PLC
Poole, UK
+44 1202 667744
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Belgravium Ltd
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www.belgravium.co.uk
Circle No. 505

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www.betheltronix.com
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Circuit Design Inc
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www.circuitdesign.co.jp
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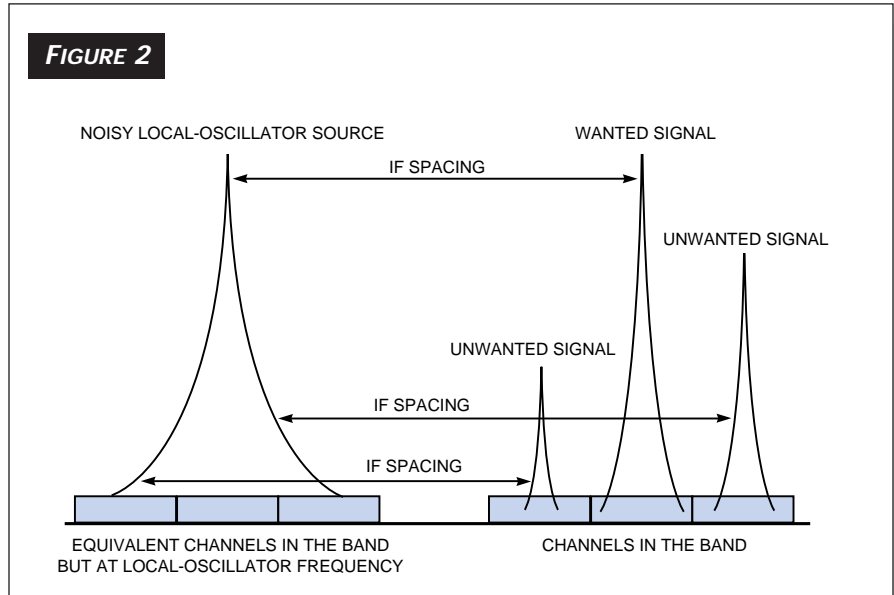
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tem design, the equipment design determines at what cost and power consumption you can meet these requirements. And, this last factor is critical for handheld equipment.

Thus, a key part of your business plan is the decision to design your own wireless link or to buy ready-made modules; the economic break-even point is likely to be approximately 2000 to 3000 units per year. If your design involves much higher volumes, consult RF IC suppliers about ASICs—some of these chips can add a μC to a transceiver, realising a one-chip solution to cost-critical requirements.

Even if you decide to use buy-in modules, some study of design issues helps you choose from the wide selection available for most applications.

Alan Wood, managing director of Wood & Douglas, offers the following advice: “In most cases, receiver design is the critical factor determining how well a system performs in the field. It is important to avoid mixing unwanted signals into the first IF output.” For example, there may be an interfering signal at the image frequency $2 \times \text{IF}$ away from the input signal. You can take this interference out of the RF filter’s passband by choosing a large enough IF. The ratio of IF-to-passband width also determines how well local-oscillator leakage into the environ-



Any channel that is IF away from a point in the local-oscillator spectrum is mixed into the IF signal.

ment is suppressed (Figures 1a and 1b).

Other sources of risk are sidebands or wide skirts on the spectrum of the local oscillator, which can cause “reciprocal mixing”—where attenuated copies of adjacent channel signals are mixed into the IF signal (Figure 2). Alleviating these problems involves compromise, most crucially in power consumption.

You can improve BER using FEC schemes, CRC, or requests for retransmission. You can trade-off this improvement for benefits to range, data rate, or power consumption. (For more detailed information, see Reference 1.)

Matthew Philips, marketing manager with Consumer Microcircuits, notes that “FEC is the friendliest technique in systems with dense traffic. At most

AUDIENCE-RESPONSE TERMINALS: A CASE STUDY

The application is a wireless data terminal for audience-response polling. The benefits of a wireless data terminal for such an application include:

- More structured choices than you can get from a show of hands.
- The choice between anonymity or attribution to individuals.
- A free choice of location (not tied to wired rooms).

Uses for wireless data terminals run from board meetings to education (real-time multiple-choice tests) to a 1200-terminal system for public meetings.

All terminals are fitted with 418- or 433-MHz transceivers. Half-duplex mode allows the base station to schedule response sequence and request retransmission of garbled data. An indoor range spanning approximately 30m limits the number of devices the base station can manage. The base station has a dual antenna to improve reception.

Dave Tuttle, production director of XTOL, says, “Our exper-

ience in audience-response measurement set us looking for a wireless solution. A pilot project with infrared links taught us that radio was the more appropriate technology.” With no full-time RF designer available, XTOL chose a complete wireless module, selected by the key criteria of power consumption and fast terminal response. The supplier provided the technical support.

According to Tuttle, the module’s type approval has been valid in all European Union markets to date—a great plus. The wireless interface complicated EMC approval for CE marking of the complete product, as the statement of compliance had to spell out exemption wave bands.

Volumes are now sufficient to justify replacing the module with ICs and components on a pc-board extension. However, says Tuttle, “in such a dynamic market it is better use of our resources to add value in the application than to take out cost. Bought-in modules have helped the product team to stay focused on the real business.” (Courtesy XTOL Ltd)



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working signal-to-noise levels, an FEC scheme increasing message length by about 33% will improve BER by at least an order of magnitude.”

In addition to various other considerations, remember that your equipment must have an integral or dedicated plug-in antenna to comply with ETS 300 220. You have a choice between designs providing 360° horizontal coverage and those providing significant directional gain—if the user can point the equipment in the right direction.

Note that you should also take into account antenna gain when testing radiated transmitter power (or spurious output from receivers) for compliance with ETS 300 220. The direction of maximum measured power performs limit checking, so the benefit of a directional transmitting antenna stems from power consumption, not absolute signal strength. For a receiver, there may be no benefit in the worst case of a single interfering signal.

New applications fuel growth

The biggest use of short-range radio has been access/alarm key-fob applications for motor vehicles. This reality is hardly surprising given the mass market for cars, the relatively small number of suppliers, and the rudimentary nature of the entry system: single-channel, one-way security-code transmission. If the message arrives garbled and nothing happens, you have just to press the button again.

Handheld data terminals are currently spreading this technology into new application areas. Helmut Meier of HM-Funktechnik reports that in Germany, no single application dominates, and end users are found in all business and state sectors. But most of the companies providing these users with radio-linked equipment are less than three years old, a sure sign of a market in exponential growth.

A typical handheld terminal has an LCD, keys, an input device such as a bar-code reader, and a wireless link to a local base station. The base station can provide access to a LAN. In roving applications, the data terminals may link directly to a third-party wireless

data network. Tasks benefiting from instant information include parcel service, warehousing, and mobile-plant tracking; more esoteric uses include restaurant-wait tracking and real-time assessment in training and education environments.

The implementation of remote metering by electricity, gas, and water utilities will trigger the real gold rush. Different models for such applications are competing for designers’ consideration. Should the base station be the domestic telephone, accessed by a no-ring call? Or should it be a dedicated lamp-post transceiver for each service, or a mobile unit cruising the streets in interrogation mode, investigating communications failure on the spot?

Whichever scheme (or schemes) wins acceptance, it is likely that each meter will eventually contain a transmitter or transceiver. Suppliers are excited by the sheer size of this prospective market but recognise that it may be some years away. If this reality allows time for a common specification to be adopted by several utilities—or across national boundaries—so much the better. EDN

You can reach Contributing Technical Editor Newell White via e-mail at newell@paston.co.uk.

Reference

1. “Increasing Data Throughput in Radio Telemetry Systems,” Consumer Microcircuits (www.cmlmicro.co.uk), November 1997.

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